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Potential Markets for Advanced Satellite Communications

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PREPARED FOR
NASA Lewis Research Center
Contract No. NAS3-26387, Task Order 1
J.E. Hollansworth

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EXECUTIVE SUMMARY

This report identifies trends in the volume and type of traffic offered to the U.S. domestic communicaitons infrastructure, and extrapolates these trends through the year 2011. Traffic in three general categories is addressed: voice, data, and video. The largest voice category, message telephone service (MTS), is analyzed separately from business voice services including private lines, private networks, and 800 and 900 services. Specific data services examined are facsimile, electronic mail and terminal operations, imaging, on-line information services, electronic funds transfer (EFT), electronic data interchange (EDI), and research networks. Video capacity demand is projected for network, cable, and educational broadcasting; video on demand (viewer choice TV); and business TV (conferencing and one-way intracorporate communications).

To describe how telecommunications service providers are adapting to the identified trends, this report assesses the status, plans, and capacity of the domestic communications intrastructure. Cable, satellite, and radio components of the infrastructure are examined separately. This report identifies existing and future applications for three types of cable: fiber optics, coaxial cable, and twisted pair. Existing and future applications are also identified for geosynchronous and low earch orbit (LEO) satellites. Satellite systems accessed by means of very small aperture terminals (VSAT) are examined separately. The radio component of the domestic infrastructure covers two types of microwave technologies: frequencies used for short-haul applications and frequencies used for long-haul applications.

The report also assesses the following major applications making use of the infrastructure:

- Broadband services, including Broadband Integrated Services Digital Network (BISDN), Switched Multimegabit Data Service (SMDS), and frame delay
- Mobile services, including voice, location, and paging
- VSAT, including mesh VSAT
- Direct Broadcast Satellite (DBS) for audio and video

The report associates satellite implementations of specific applications with market segments appropriate to their features and capabilities. The volume and dollar value of these market segments are estimated. For the satellite applications able to address the needs of significant market segments, the report also examines the potential of each satellite-based application to capture business from alternative technologies.

GENERAL COMMUNICATIONS TRAFFIC TYPES, VOLUME, AND TRENDS

Demand for telecommunications capacity is the result of a huge, slowly growing base of voice traffic coexisting with video and data services, some of which will grow at a much faster rate.

MTS will be of continuing but decreasing importance. MTS, the largest component of domestic traffic, has recently grown at 12 percent per year, but this high rate reflects factors that will diminish during the forecast horizon. Telecommunications deregulation in the 1980's eliminated the practice of subsidizing local calls with higher long-distance charges. Deregulation also promoted price competition. The MTS market is approaching saturation as the effect of these one-time factors abates. Over the 1991 to 2011 forecast period, growth will average 7 percent per year.

Booz·Allen anticipates that private lines will undergo price competition to offset loss of traffic to virtual private networks. However, pricing will not fully offset losses as virtual private networks evolve into a substitute for private lines. The result will be negative private line growth after 2000, and a compound annual unit growth rate of less than 1 percent during the forecast period. This will be a net result of 4 to 5 percent growth until 2001, followed by an offsetting decline. Virtual private networks will grow at 7 percent.

The 800 service traffic will grow slightly faster than its recent trends would indicate. Unified national signaling and database systems will offset the near-term effects of a slow economy, which will induce limited substitution of 900 lines for customer service and sales. Growth will begin to slow until 2000, as mild market saturation sets in. The net effect of these factors will be 7 percent compound annual growth from 1991 through 2011.

Caller-paid inbound services, or 900 services, have suffered from abuses and the consequent threat of regulation. As these short-term effects abate, significant growth will ensue when 900 services cut prices to position themselves as substitutes for some 800 offerings. Annual growth is expected to average 7 percent during the 1991 to 2011 forecast period.

Multiple generations of fax machines are in use. This will shorten life cycles and make changing growth rates an evident effect of innovation diffusion and market saturation. Price competition, penetration of residential markets, and new features made possible by ISDN compatibility will offset and defer saturation of current markets. However, improved compression and the emergence of electronic mail as a fax substitute will greatly reduce the capacity demands of the growing installed base of fax terminals. The net effect will be an 81 percent decline in fax traffic in the course of the 1991 to 2011 forecast period.

Electronic mail is likely to be the most dynamic component of data traffic. Electronic mail will evolve into a nearly ubiquitous service (160 million users), driven by increasing interconnectivity among applications and software-based directories. Frequency of use will increase during the forecast period, and messages size will increase as data services are integrated. An explosive annual growth averaging 84 percent will result.

Computer terminal operations are the background against which specific data services are projected. Computer terminal operations will grow by almost 12 percent annually from 1991 through 2011 as computer processing becomes more distributed and interconnections proliferate.

In this study, Booz·Allen does not project the growth of imaging transmissions, which will grow rapidly from a minimal base. Imaging traffic growth depends strongly on the progress of integration with other types of data and with advances in storage and retrieval technologies.

On-line information services will grow by 22 percent annually through 2011, although faster potential growth will be retarded by human factors and concomitant lack of integration into work and consumption patterns. The more specialized services offered by research networks have shown explosive growth recently, but their growth has been confined to military and academic users, along with individual users in corporations. We do not project research network growth, because it depends strongly on the extent to which commercial ventures transform existing networks into services that meet a broader range of needs.

EFT transactions for interbank and consumer transactions will increase to more than six times their current level from 1991 to 2011. Interstate banking and proliferation of point-of-sale terminals will drive this growth, along with moderate consumer acceptance of paperless transactions. EFT traffic and channel requirements will grow at a compound annual rate of 10 percent.

The growth of EDI will be retarded in the near term because local exchange carriers are prohibited from providing value-added services. Other near-term inhibiting factors include prospective users' security concerns and lack of knowledge of the benefits of EDI. As these problems are addressed, technological advances will cause growth to accelerate sharply through 2000. Sustained rapid growth would require significant changes to computer architectures, which are unlikely to be evident until after 2011. From 1991 through 2011, EDI will average 9 percent annual growth.

Capacity for network broadcasters will grow more slowly than requirements for data services. Compression technology and availability of fiber optic capacity for point-to-point transmission will tend to accelerate channel growth by reducing transmission cost. The advent of high-definition television (HDTV) and viewer-choice television will also stimulate demand for additional channels. However, competition from cable and other video delivery systems will moderate this growth somewhat. The chief effect will be 57 percent greater efficiency in bandwidth use due to improved compression. The net effect will cause required network broadcast video capacity to decline by 50 percent in 20 years. By contrast, cable channels will average relatively constant annual growth of just under 5 percent. Cable broadcasters' response to competition from local exchange carriers will be to segment their programming for more specific interests and to serve their audience with more channels. Transmission economies accruing from video compression advances will result in a 30 percent decline in transmission requirements.

Educational television growth depends on technological advances that cut cost and on user acceptance, which has been cautious to date. The net effect of increasing user acceptance and compression efficiencies will be a 39 percent decline in bandwidth demand during the forecast period.

Business TV growth is an amalgam of services penetrating the corporate market at different rates. Services are differentiated by image quality: full-motion video (45 Mb/s) will grow relatively slowly because of its cost, while the growth of limited-motion video (56 to 384 kb/s) will be constrained by its lower quality. Limited full-motion video (384 kb/s to 2.048 Mb/s) will exhibit the highest traffic growth in the next 15 years because compression technology will offer users an improved tradeoff between cost and performance. From 1991 to 2001, the average 12.7 percent per year increase in daily conference-hours is more than compensated for by decrease in bandwidth requirements due to compression, resulting in a net two-thirds reduction in bandwidth demand. From 2001 to 2011, the annual increase in daily conference-hours of 1.4 percent per year combines with a shift toward higher-picture-quality services to result in an annual increase of 2.7 percent in bandwidth demand.

It is too early to develop meaningful projections for the long-distance transmission component of Viewer Choice TV because of unresolved business and cost issues (see section 2.5.5). Using many assumptions, an example shows that it could develop into the second largest consumer of inter-local access and transport area (LATA) bandwidth by 2011. Growth and volume will be negligible until 2000, at which time regulatory restrictions and local loop constraints will have been removed and business relationships will have been established. After 2000, VCTV could grow at 16 percent per year.

TELECOMMUNICATIONS INFRASTRUCTURE STATUS AND PLANS

Today, after years of conversion from coaxial cable and microwave by interexchange carriers (IECs), long-distance phone service in the United States is primarily carried on single-mode optical fiber, with only a few carriers maintaining digital microwave communications in areas with rough terrain or low population density. Conversion to fiber began in 1983, with fiber installation proceeding rapidly. The rapid installation was a result of the 1982 AT&T divestiture agreement, which intensified competition among interexchange carriers on the basis of capacity and quality. For competitive reasons, long-distance carriers began installing fiber in their networks and marketing their services as providing connections with clarity and quality superior to older technologies. This competitive environment resulted in significant capital expenditures (more than $5 billion as of 1986) by nine of the nation's leading long-distance companies to provide long-distance fiber communications. By 1987, the bulk of the long-distance phone service had been converted to fiber. Today, Sprint, with its 23,000-mile all-fiber network, provides long-distance service that has been entirely fiber since 1988. MCI reported that as of 1990 its domestic network was 99% digital and targeted at 100 percent by February 1992. Most of MCI's network is fiber, with digital radio remaining in some locations. As of 1988, AT&T had more than 23,000 fiber route miles in place and was planning to lay an additional 10,000 miles by 1993. By December 1991, AT&T had installed 31,400 of its planned 33,000 fiber route miles. AT&T plans an entirely digital network by 1993, with only a small fraction of the digital microwave radio remaining. Other interexchange carriers, such as WilTel, RCI Long Distance, ATC, Consolidated Network Inc., Mutual Signal Corporation, Communications Transmission Inc., and Norlight, accounted for an additional 22,000 fiber route miles across the country by 1988.

Local exchange carriers (LECs) began installing fiber around 1987, the same time as long-distance carriers began to slow their investments. The Department of Commerce estimated that the Bell Operating Companies deployed about 1.5 million miles of fiber by the end of 1988. These lines connect the carrier to the IEC networks and interconnect LEC central offices. Today, the LECs have virtually completed their interconnection plans.

Even with all the expansion by the IECs and LECs, the use of fiber has been almost completely confined to interoffice trunking. Penetration into the local loop, where traffic volume is lower, distances are shorter, and costs per subscriber line have been high (presently around

$1,600), has been slow. Because of the cost, LECs are not expected to begin major installation of fiber in the local loop until around 1995.

Several issues are now pressing the cable TV industry toward fiber networks. Due to the lifting of government restrictions against LECs providing information services, the major network broadcast corporations (NBC, ABC, and CBS) are investigating with the IECs the transmission of network programming over their fiber networks. This move could pave the way for the high-bandwidth transmission necessary for HDTV. When the LECs have installed their fiber networks and with permission from the Government, it would be possible to receive network programming over fiber optic local loops. These issues are creating an environment that is driving the cable TV industry toward the use of fiber optics in their networks.

The use of Ku-band satellites is continuing to grow because of the attractive cost advantages of VSAT systems using higher-powered Ku-band transmissions. The number of Ku-band transponders in orbit will nearly double the number of C-band transponders by the mid to late 1990s [3]. GTE Spacenet Vice President David Fiske forecasts that Ku-band video transponder use will equal C-band use around 1995.

The change from C-band to other bands, however, will occur slowly. Several top satellite service providers, including Hughes Communications and GE American Communications, are committed to continued services extending through this century. According to Hughes, more than 15,000 commercial C-band installations exist at cable headends, television stations, and other businesses around the country. More than 90 percent of all domestic television stations have a C-band satellite capability. This represents a significant investment in C-band terrestrial plant, ensuring continuing C-band use. There are estimated to be nearly 3 million privately owned C-band backyard satellite dish installations. Despite a major decline in sales of home television receive-only (TVRO) equipment caused by the scrambling of cable programming services, there still exists a significant user base to keep the C-band market viable throughout this century.

A number of new satellites carry both C-band and Ku-band transponders, permitting the implementation of networks that take advantage of the characteristics of both frequency bands. Nonetheless, the number of satellites recently launched, planned, or in construction shows an unmistakable move toward Ku-band as the dominant satellite delivery technology in the near future.

Recently the Federal Communications Commission (FCC) granted authority for Norris Satellite Communications, Inc. to proceed with construction, launch, and operation of the first U.S. commercial telecommmuncations satellite operating at Ka-band (30/20 GHz). The experimental NASA Advanced Communications Technology Satellite (ACTS) satellite, which operates at Ka-band, is scheduled to be launched in 1993.

The main driver behind the interest in LEO satellite systems is interest in the cellular telephone, fax, and voice messaging businesses. Recent estimates are that, as international economic integration progresses, the number of subscribers to mobile services could reach 100 million worldwide by 2000.

Unlike terrestrial cellular systems, in which users move though adjoining "cells" or areas of coverage, mobile satellite systems would beam a moving cell onto the surface of the earth.

LEO satellites would be able to provide cellular phone service to a wide area without the delays associated with geosynchronous systems.

Motorola Corporation in 1990 announced plans to develop a global cellular network called Iridium. This system will provide worldwide point-to-point communciations. It will provide telephone service, facsimile, data transmission, global paging, radio determination satellite service, and global positioning service for millions of users. The system will be based on the deployment of 66 small satellites positioned in 6 low-altitude polar orbits with 11 satellites in each plane.

Fiber optics offers almost infinite bandwidth and transmits data with virtually no errors. Fiber began to dominate the long-haul telecommunications traffic during the 1980's. The microwave market not addressed by fiber optics was being challenged by satellites. For example, during the 1980's much of the cable and broadcast TV market that had used microwave systems migrated to satellite transmission. The increased use of fiber optics and satellites has drastically reduced the use of long-haul microwave transmissions. There are still microwave systems in use, but most applications that were historically based on microwave technology have been or will be converted to other transmission media.

Significant expansion of short-haul microwave technology is expected in the future. Several new technologies, including cellular and personal communication networks, will spark new growth in the microwave industry. Short-haul microwave serves as a complement to fiber optics and is therefore not in direct competition. Because of short-haul's advantages and advancements in technologies, it has not experienced the same loss in market share as long-haul microwave. Short-haul microwave technology should continue to experience growth with the advent of new applications that fit into its market niche.

APPLICATIONS

Applications expected to dominate use of the communications infrastructure through the year 2011 that are examined in this report include: broadband technologies, fixed satellite systems, integrated video, and mobile satellite systems. We project with a high degree of confidence that these applications will be technically feasible and economically viable within the time horizon of this study. Additionally, we expect each of these applications to account for a significant amount of traffic generated. Status, plans, deployment coverage, cost, and traffic projections are examined for each application presented.

Broadband Technologies

Emerging high-speed data transmission requirements, a changing ratio of voice to data traffic, and the emergence of increased video traffic are spurring the development of advanced technologies to support anticipated demand for broadband communication services. Common to all these new services is the rapid development of efficient packet technology as the basis for new network architectures to support these services. Packet technology is replacing circuit technology because of the benefits it brings to rapidly growing end-user applications such as local-area network (LAN) interconnection.

Three emerging broadband services analyzed in this report are frame relay, SMDS, and BISDN. Although available today, frame relay and SMDS have been included in this study because their deployment and user acceptance over the next several years will serve as indicators of demand for broadband services. Over time, we expect to see frame relay eventually migrating onto BISDN as a bearer service, and SMDS serving as an access technology for BISDN.

Frame Relay

Frame relay is an emerging data access standard that is being used to interface private network backbone switches and is also being offered as a carrier-based service. It is based on a variable-length packet structure and is capable of supporting data applications at transmission speeds up to 2.048 Mb/s. More than 50 manufacturers have announce plans to develop products that support frame relay and more than 19 carriers have plans to offer frame relay services.

The most likely scenario for the deployment of frame relay over the next 5 years is a hybrid approach in which traffic will pass between private and public networks. Hybrid networks will reduce leased-line costs for users by allowing them to connect their private networks to public networks by using packetized facilities such as asynchronous transfer mode (ATM). Also, the hybrid approach will provide users with significantly greater flexibility in configuring and reconfiguring their networks, resulting in further cost savings.

Demand for frame relay services will primarily be driven by the demand for high-speed LAN-to-LAN interconnects. We expect frame relay applications to account for a significant amount of data transmission traffic until cell-based transmission technology such as ATM becomes widely available. Frame relay traffic is expected to experience rapid growth through 2000, when some of this traffic will migrate onto BISDN where available and some will migrate to higher-bandwidth alternatives such as SMDS.

SMDS

Bellcore developed SMDS as a carrier service concept for connectionless data service. It is intended to provide a high-speed, central office-based metropolitan area network that will give users an alternative to private systems. The primary application for connectionless data transfer is for high-speed (DS-1 or DS-3) LAN-interconnect type service. While frame relay can support both connection-oriented and connectionless data transfer at lower transmission rates, SMDS is more narrowly focused to support only connectionless data transfer at significantly higher rates.

SMDS, having both DS-1 and DS-3 access rates, will be attractive to both large- and small-to-medium-sized businesses if priced competitively. Initial interest in the service will focus on the DS-1 access rate and will be deployed to customers already having facilities that can support this transmission rate. Over time, larger business customers will migrate towards the DS-3 access rate to meet higher-speed LAN interconnect requirements. Emerging technologies such as high bit-rate digital subscriber line will allow the economical upgrade of the existing copper plant to support the DS-1 access rate and will place SMDS within the reach of small-to-medium-sized businesses.

Demand for SMDS will be driven by the need for LAN-to-LAN interconnects that can support higher speed data transfer than is available with other technologies such as frame relay. As LAN speeds increase to rates of 16 Mb/s for token rings and 100 Mb/s for fiber distributed data inferface, high-speed LAN-interconnect services such as SMDS will be essential to support the trend towards distributed processing over greater distances. We expect to see rapid growth of SMDS traffic through the year 2000 and a slowing of growth as SMDS lines are upgraded to support ATM and are used as access links for BISDN or supplanted by BISDN for new service applications.

BISDN

BISDN represents the next major step in the evolution of the public switched telephone network. It is intended to support a host of interactive and distribution services ranging from voice to high-quality video. Based on an infrastructure of optical fiber transmission and fast-packet switching systems, BISDN can reduce the need for service-specific networks, thereby reducing overall network operation costs. BISDN is intended to extend the integration provided by ISDN within the loop plant to include the switching, signaling, and transport facilities to support broadband services.

All major local exchange and interexchange carriers are aggressively prosecuting plans to upgrade their networks to support broadband service offerings. Generally, networks are being upgraded in two phases: expansion of synchronous optical network-based fiber optic transmission facilities and upgrade of the switching fabric to include ATM capabilities. Local exchange carriers are deploying various fiber-to-the-curb and fiber-to-the-home systems to support extension of broadband transmission capabilities to the customer premise. Carriers are planning to deploy broadband switching capabilities to support large business customer applications first, then gradually achieve widespread upgrade of their switching fabric to support small business and residential customers.

Despite the inherent advantages of a universal BISDN, development and investment costs associated with deploying such a network on a large-scale basis are prohibitive in the short term. Therefore, a major technical challenge that faces the communications industry is to allow the time-phased implementation of BISDN. The industry consensus is that the migration strategy will include four phases: deployment of broadband transmission capabilities to the customer, introduction of BISDN services, integration of metropolitan area networks into BISDN, and the introduction of television distribution via BISDN.

While a point-to-point application such as BISDN is not cost-effective for the major part of TV broadcasting (point-to-multipoint), there are many TV distribution applications for which BISDN is suitable. Examples are program collection (news, features, previously-recorded shows) and downloading of video to VOD "jukeboxes." These are non-real-time applications. Even real-time transmission need not present an insuperable problem: the maximum delay can be bounded with a very high probability; together with the very low price of memory, one can consider downloading with only very slight transmission delay. For entertainment purposes, an occasional missed frame that is interpolated by the decompression logic would not be noticeable.

Demand for services supported by BISDN can be analyzed as two major segments, business and residential. Business services will be characterized by high-bit-rate connectionless data transfer to support the growing demand for information retrieval and transfer among computers, and variable-bit-rate services to support rapid growth in image traffic. Residential services will be focused on providing entertainment programming and convenience services such as in-home shopping and banking. Business applications will account for initial BISDN traffic in the 1998 time frame with traffic continuing to grow as existing services are migrated to BISDN and additional capabilities are introduced. As carriers continue to deploy fiber optic transmission systems in the loop, broadband services will be made available to a growing number of residential customers beginning around the year 2000, and reaching widespread availability by the year 2011.

VSAT

VSAT networks are an alternative to terrestrial-based networks for primarily closed user group applications. These networks can be configured for full-duplex transmission, as in interactive networks, or simplex transmission, as in one-way data broadcast networks, depending upon specific user applications. In addition to traditional VSAT networks that employ a large hub earth station, mesh VSAT networks are emerging as an alternative solution to a variety of new customer networking requirements. Advantages of VSAT networks include the capability to provide economical private communications with a high degree of reliability, serve geographically-dispersed locations, and support easy reconfiguration or network expansion.

Mesh VSAT networks can be based on two approaches: enhanced terminals using traditional satellites equipped with standard "bent-pipe transponders," or advanced next-generation satellites equipped with on-board switching capabilities. One manufacturer, Spar Communications, is offering a mesh VSAT system that does not require satellites equipped with on-board switching capabilities. This type of mesh VSAT allows communication among terminals without a hub station by distributing intelligence normally located at the hub to the terminal stations. NASA's ACTS program is pursuing development of a next-generation communication satellite that will have on-board switching capabilities and will support mesh VSAT networks.

Due to the closed user group limitations and the relatively high cost of mesh VSATs, VSAT and mesh VSAT systems will be best suited to customized applications. These applications will be primarily data transmission including, facsimile, e-mail, terminal operations, EFT, and EDI. Additionally, video traffic generated by educational and business television will continue to be VSAT applications.

DBS

DBS is a term used to describe a satellite delivery system designed to provide video, audio, and data services directly to the end-user. One distinguishing characteristic of DBS is the relatively high power of the broadcast signal, which allows the use of relatively small receiving antennas. Currently, the U.S. has no "high-powered" DBS systems in operation. Eleven applications are on file with the FCC for video systems and four are on file for audio systems. Additionally, there have been several inquiries into the viability of using DBS for other types of service delivery including data services, news services, and educational programming. Although these applications indicate a high degree of industry interest, it is extremely unlikely that all the DBS proposals before the FCC will reach the operational stage.

In the DBS video arena, Hughes' DirecTV will be the first operational DBS system in the U.S. with a launch date scheduled for December 1993. The Hughes system will provide direct broadcast television to the coterminous U.S. with an initial programming package of approximately 20 channels, similar to those provided on cable television. None of the other DBS applicants have progressed to the point where concrete plans exist and launch dates have been scheduled.

Integrated Video

The component technologies of video telecommunications have been evolving for more than 25 years without achieving widespread user acceptance. Since 1980, two important trends have improved the prospects for this application: improvements in video coding have resulted in better image quality at lower bandwidth and, largely due to VLSI, equipment prices have declined significantly. Additionally, usage-sensitive costs such as transmission costs have dropped significantly due to competitive pressures and the introduction of fractional T1 services.

Industry activity focuses on developing desktop or personal video systems capable of using plain old telephone service (POTS) lines for transmission. Designers for equipment suppliers feel that the compression level of codecs for POTS has reached the limit imposed by low POTS transmission rates, and more bandwidth will drive quality improvements through the year 2000. For example, image quality improvements could be made possible as a result of the increased bandwidth available using ISDN.

The primary factor affecting the volume of integrated video traffic is the integration of voice and data services. ISDN will be a critical factor in promoting the growth of integrated video. Industry projections are that full feature video telephony based on the ISDN multi-use bearer group will be available in 1995. This means that both video conferencing and video telephony will be technically able to provide integrated video features. However, video telephony will concentrate for the near term on low bandwidth to capture residential and business markets that rely on POTS rather than ISDN.

MSS

Mobile satellite systems (MSS) are designed to deliver a range of communication services to a wide variety of terminal types. Mobile satellite terminal platforms include land vehicles, aircraft, marine vessels, and remote data collection and control sites. Portable terminals used for these services are briefcase size, but may be reduced to handheld sizes for future systems. Basic mobile services supported by these systems include voice, data, paging, and position determination. Systems can also be configured to provide services among a closed user group, such as a government agency or company, with satellite communications being provided between mobile terminals and a base station.

A variety of service providers are emerging in response to growing demand for mobile satellite services to support land, aeronautical-, and sea-based applications. Inmarsat and Qualcomm are providing service in the U.S., demonstrating the economic viability of these systems. However, most potential commercial mobile satellite service providers' systems are in the planning stages with filings before the FCC. Service providers have expressed a wide variety of spectrum requirements for mobile satellite systems ranging from 1 MHz to 220 MHz of bandwidth in L-, S-, C-, Ku-, and Ka-bands. Additionally, a variety of concepts have been proposed for these systems, ranging from the use of new or existing geostationary satellites to systems based on low- or medium-altitude satellites.

The industry consensus is that MSS will experience rapid market growth over the time horizon of this study. As people become more reliant on telephone systems for voice and data connectivity, they are also demanding greater freedom from the fixed-plant wireline systems.

MSS will serve markets without cellular service coverage and offers the potential to greatly enhance productivity for a variety of business and mobile office applications.

SATELLITE-ADDRESSABLE MARKETS

Among the applications that will dominate the nation's infrastructure to 2011, several could be served by satellite technology. To identify feasible satellite implementations of these dominant applications, we analyzed each application along three interrelated dimensions: technical adequacy, competitiveness, and user acceptance. The application groups that we found to have significant potential for satellite addressability are broadband services, VSAT, direct broadcast satellite, and mobile satellite services. Integrated video was not of sufficient volume to be satellite addressable independent from other applications. However, integrated video, as an end-user application, is possible through satellite enhancement of BISDN or through VSAT, and is therefore handled as a subset of those sections.

Technical adequacy refers to the ability of a technology or service to meet the technical communication requirements of an application. Competitiveness is defined in this analysis as the potential of a technology to become a substitute for other means of providing a communication service. Competitiveness also identifies the competing technologies and the level of competition among companies in the industry segment being examined as well as among those companies in other segments that will provide competing technological solutions. User acceptance has both an objective and a subjective component. Although some segments of satellite technology have aesthetic considerations that limit or hinder user acceptance, such as restrictions placed by communities on the installation of earth stations (objective), most issues of user acceptance deal with the product's quality of transmission and ease of use to determine the product's subjective utility to the consumer. Cost has an indirect effect on the level of user acceptance by affecting the perceived utility of the application.

Each application group, as defined in section 4, is segregated into types of traffic that are expected to be major consumers of infrastructure in the next 20 years.[1] The major types of traffic are voice, data, and video; each is evaluated on its constituent traffic elements. Based on the results of analysis, each traffic type is given a weight reflecting the overall addressability of the application and applied to the total traffic estimates for each type to derive the quantity of traffic that can be addressed.

Broadband ISDN

Broadband services provide the capability to move vast amounts of data on the order of hundreds of megabytes in a matter of seconds. These services will be provided by frame relay, SMDS, and BISDN. Presently there are no satellites capable of providing these services, but the potential exists for these applications to become a major portion of total national traffic.

The need for high bandwidth data transmission will increase in the future because of the increased transmission of image data and of megabyte file transfers between supercomputer networks. Both of these data types exist within a closed user community. For instance, T1 speeds are already commonly used for LAN-to-LAN interconnection and for backbone transmission in

[1] See section 2, General Communications Types, Volumes, and Trends for a complete list and description of the traffic types.

large research networks such as NSFNET. Point-to-point video is also a potentially large user of BISDN services.

From a technical standpoint, BISDN can be adequately transmitted via satellite, but the competition from terrestrial carriers will be intense. The most attractive niche for satellite enhancement of BISDN will be to closed networks of remote users. User acceptance will be greater for traffic that is not affected by the 250-millisecond transmission delay for geosynchronous communications.

Mesh- and Star-Connected VSAT

Present satellites are not capable of supporting mesh-connected VSATs with bit rates greater than 1.544 Mb/s. However, future satellites may incorporate high-power spot beams and switching capabilities, thereby allowing manufacturers to develop less expensive mesh VSAT terminals. The significant installed base indicates that technical adequacy of VSATs has been achieved. Yet the competitive pressures faced by VSAT, whether star- or mesh-configured, from other terrestrial means of providing a communications path will be such that prices of terminal equipment and airtime must continue to decline. User acceptance is particularly strong for VSATs, especially mesh, because VSATs are capable of providing high-quality transmission for data, video, and, with some constraints, voice with great reliability and sometimes with quicker response times than is possible with terrestrial circuits.

Direct Broadcast Satellite

Because DBS is by definition satellite addressable from a technical standpoint, the most important issues focus on competitiveness and user acceptance. Competition in the market in which DBS will participate is already very strong. Significant barriers to entry that must be overcome for DBS to be successful include procuring a license to operate, distributing DBS terminals, and securing an adequate supply of programming. Because the cable franchises already have a very strong foothold in the urban markets, DBS will have the greatest chance of success by filling the unmet needs of the approximately 30 million homes that are not presently passed by cable. In this market, DBS will compete only with a subset of audio and video delivery modes. Present technology makes TVRO a very expensive investment for most users because of the required large receiving dish, whereas DBS, with its greater signal strength, allows the use of 18-inch-diameter dishes. In addition, DBS will have a competitive advantage over both cable and terrestrial television broadcast because of its potential to deliver HDTV-quality progamming to a mass audience much sooner. The overall higher quality of DBS signals, whether it is HDTV to urban subscribers or the present system to rural subscribers, is a strong factor in favor of long-term user acceptance.

Mobile Satellite Services

Satellites can address needs for four specific mobile services: voice, data, positioning, and paging. On the basis of overall user utility, satellite is the most attractive medium for each of these services. Satellites have unique advantages in market segments requiring global or broad regional coverage. If users need service only over limited distances, terrestrial radio has significant cost advantages, particularly in the paging market. But for voice, data, and positioning, satellites can offset lower terrestrial costs with higher capacity and lower bit error rates.

SATELLITE CAPTURABLE MARKETS

Mesh VSAT can address the need for lower data rates (less than 45 Mb/s) supplied by broadband services applications. Mesh VSAT can also provide integrated video functionality. The most promising VSAT market is for private networks (i.e., closed user communities).

The results of Booz·Allen's analysis indicate that the private network market can be divided into segments according to two characteristics of the private network's user community: size and geographic dispersion. The number of users affects VSAT cost per node because more users can share transponder or hub costs among a larger number of terminals. Geographic dispersion affects the cost of nodes in private line networks because longer links cost more.

Comparative cost structures for conventional (hub and spoke) VSAT and terrestrial private lines have changed in favor of VSAT since 1989. In 1989, VSAT was more economical for networks of 400 terminals or more as long as users were located more than 225 miles apart. Even with smaller distances between users, larger networks can compensate for shorter and cheaper terrestrial links. When users average 100 miles apart, VSAT is less expensive if 2,800 terminals are linked.

Under assumptions that network size has a skewed distribution and network dispersion is uniformly distributed, conventional VSAT technology was the low-cost solution for an appreciable fraction of networks with fewer than 3,000 nodes.

- Forty-eight percent of users are capturable by VSAT networks competing with private line networks averaging 6 drops per line, if a 7-year evaluation period is used.
- Fourteen percent of the market is capturable if prospective users compare VSAT to private networks with 6 drops per line over a 5-year period.
- Thirty percent of the market is capturable from private line networks with 12 drops per line, if users evaluate investments over a 7-year period.

Under 1992 pricing, conventional VSAT is cost competitive for private networks with more than 300 users, even when the distance between terminals is as low as 25 miles. When the average dispersion of the user community puts terminals an average of 50 miles apart, VSAT networks with 200 terminals are less expensive than terrestrial alternatives.

This situation permits VSAT-based technologies to provide a lower cost alternative to private line networks composing 75 percent of the private network market. We can predict with confidence that 75 percent of users would now choose satellite over other alternatives if cost were the sole consideration. Of course, cost competitiveness is not the only factor affecting market share. Before VSAT could approach a 75 percent market share, other factors would likely constrain its penetration, such as a competitive response by terrestrial carriers.

The potentially capturable shares listed above are shares of the total market, but they exclude networks with more than 3,000 users and networks with terminals separated by more than 325 miles. It is likely that VSAT can be a competitive solution for these larger and more dispersed networks.

From 1989 to 1992, the competitive cost position of VSAT has improved markedly, primarily because of lower earth station cost. For three reasons, however, cost-competitiveness must be qualified to constitute a complete gauge of VSAT's business potential. First, terrestrial carriers could compete more aggressively on price. Firms, at least the non-dominant common carriers, would probably price more aggressively if they judged the risk of VSAT competition to be greater than the risk of disrupting the industry's relatively stable and predictable pricing policies. Second, terrestrial carriers have significant noncost competitive advantages: for example, high existing market share and entrenched customer service and sales networks. And third, long-distance telecommunications firms have recently succeeded in de-emphasizing price competition. The effect of these changes is to increase the importance of the carriers' ability to tailor solutions to user needs. Competitive conditions have undoubtedly slowed the diffusion of satellite innovations, resulting in market shares much lower than satellite could capture based solely on cost.

Mesh VSAT systems are under commercial development. Mesh VSAT is not yet ready for widespread commercial use, but technological advances are likely to make this solution cost-competitive within the forecast horizon of this study.

With a 1992 pricing structure, mesh VSAT is not cost-competitive. Mesh VSAT terminals usually assume some hub functions, leading to increases in their cost. Current vendor estimates are approximately $50,000 per terminal. Although hub costs are considerably reduced, this does not offset the increased cost per user relative to conventional VSAT systems.

If mesh VSAT earth station prices decline as rapidly as conventional VSAT in the near term, mesh VSAT is not cost-competitive for networks with fewer than 3,000 user sites until 1998. But in 1998, a substantial fraction of the most dispersed networks come within reach. Networks with 200 nodes are cost-effective mesh VSAT applications if users average 175 miles apart. VSAT may be cost-competitive if users average just 125 miles apart. In 1 year, the market share that mesh VSAT can capture on a cost basis jumps from almost 0 to more than 50 percent. If VSAT earth station cost declined more slowly, by 20 percent per year, in 1998 a mesh VSAT solution would be more costly for networks with fewer than 3,000 users. By 1999, only 21 percent of the market would be capturable.

Under the conservative assumption of 20 percent annual earth station cost reduction, Booz·Allen believes that by 1999, 21 percent of users will definitely choose mesh VSAT over other alternatives if cost is the sole consideration.

Just as in the terrestrial VSAT market, market penetration will lag its full potential because the innovation must diffuse through the user community. The private network market will have significant factors that will retard acceptance of mesh VSAT innovations, whether it is using terrestrial or satellite networks. Terrestrial network users will have established relationships with competing suppliers. Satellite network users may also have inhibiting influences—for example, significant investment in conventional VSAT systems.

It is likely that after 1998, price declines will moderate while mesh VSAT systems diffuse through an increasing percentage of the capturable market. Mesh VSAT will not necessarily cannibalize business from hub and spoke systems, however. Hub and spoke architectures are likely to remain attractive for applications with data that principally flow to or from a central point.

Broadcasting and Direct Broadcast Satellite

DBS technology can be used to broadcast audio or video. Broadcasting markets have different characteristics than private network telecommunications markets. Competitive viability in broadcast markets results not from traffic-based revenues but from charges to users or advertisers. For this reason, the competitive position of broadcast media is unrelated to the number of user channels. Competitive position depends on the revenue that can be generated from the content of a limited number of channels. Also, in the consumer market for broadcast entertainment, subjective criteria play an important role by comparison with the VSAT market.

Video DBS competes with broadcast television, cable, videocassettes, and theaters. In the future, video DBS may also have to compete against video on-demand supplied by local exchange carriers. A notional consumer choice model indicates that DBS is the least attractive delivery mode for price sensitive market segments. DBS is likely to be more attractive than theaters to segments where convenience is more important because DBS offers home access and greater selection convenience.

Although DBS is rated less attractive than most competing delivery modes, this does not mean that it will not be chosen by consumers. All of the four currently prevalent services—cable, television, theaters, and video stores—coexist in most areas. Individual viewers often use several services because services occupy niches defined by program content or novelty, and because viewers' strength of preference for program content and convenience changes continually.

One obvious niche for DBS is based on location. Areas where some alternatives are distant or unavailable are more likely to adopt and use DBS. For example, the 12 percent (as of 1990) of homes not passed by cable are a natural market. Areas with poor television reception have long been natural DBS niches, particularly if they are remote. Areas with low population density handicap services like video stores and theaters that do not offer home access. In the future, the single most ubiquitous competitor to DBS will probably be LEC video on-demand offerings, which are are potentially available to all telephone subscribers.

The relative attractiveness of DBS increases dramatically, to second or third place from fourth or xixth place low figures 6-19 and 6-20, if earth station prices fall into the $100 to $200 range.

HDTV technology has the potential to make image quality an important factor distinguishing different delivery modes. Adoption of a digital HDTV standard could give DBS an important competitive advantage. DBS could be the first medium to broadcast HDTV using digital decoders that could interchangeably display HDTV and conventional resolution TV. This would differentiate DBS from its terrestrial competitors and improve its competitive position. It may then be possible to price DBS services higher than other video offerings.

Direct Broadcast Satellite-Radio (DBS-R) has characteristics that are very different from those of the existing terrestrial radio broadcast industry. One important attribute is that a different receiver is required. Another important attribute is that satellite is inherently suited to a national, or at least regional, audience. A third key DBS-R attribute is that it can offer a large number of channels, up to 100 in some configurations.

We conclude that sufficient penetration of the national radio audience can support the capital expenditure of a DBS-R satellite, whether the system is supported by advertising or by subscription. The advertising cost per thousand listeners of DBS-R can compete with terrestrial radio rates because the higher capital cost can be offset by greater reach.

Assuming a 1997 start date, this analysis indicates that the value of revenue produced by a DBS venture could exceed $500 million by 2001 and $1.2 billion by 2006. However, these figures are contingent on achieving an audience of more than 80 million listeners in 6 years. This presumes very inexpensive receivers and audience acquisition costs that dwarf the cost of space segment investment. Consequently, advertising supported DBS-R would be a very risky proposition, particularly in the near term because of competitive conditions in the terrestrial industry.

A subscription-based service could achieve an equivalent return with a far smaller audience than that required for an advertising-based service: just 2.7 million listeners in year 10. Total audience acquisition cost is correspondingly low, about 2 percent of the expenditure required for a service supported by advertising. The venture could begin to make a profit in the third year. The business risk of a subscription service is far lower because of the smaller scale initial outlay. In this case, DBS-R revenue could have a value of $241 million in 2001 and $293 million in 2006 if the business were launched in 1997.

Competitive capture is less of an issue for a subscription DBS-R service. Satellite pay radio is essentially a niche market for a new service. Pay radio and advertiser-supported radio draw on two different sources of revenue, so direct competition between the two is impossible. From the standpoint of the terrestrial radio industry, however, pay radio poses a threat, because it may reduce the audience for terrestrial radio.

Satellite provision of mobile services has strong potential, due to its superior performance and significant economies of scale. Booz·Allen analysis rated satellite higher overall than any other medium that could be used to supply cellular services. Key satellite performance advantages include flexibility to accommodate highly mobile and distant users. The most important satellite cost advantage is the ability to cover larger areas with minimal incremental investment. This scale economy makes satellites less capital-intensive for service areas as small as 30 miles in radius. Booz·Allen projects that mobile satellite will capture a preponderance of the addressable market.

Cross-impacts among terrestrial and satellite-based applications result from substitution potential or complementarity. More use of frame relay would mean deferred adoption of the more advanced broadband services, perhaps because frame relay becomes accepted as a standard and vendors enhance it with additional features. For this reason, use of frame relay is negatively related to SMDS, BISDN, and mesh VSAT, because lower rate data traffic can be carried among closed user communities on either application.

Similar inverse relationships link other broadband technologies. As SMDS use increases, SMDS will supplant near-term use of frame relay. Conversely, BISDN will supplant SMDS in the later years of the forecast horizon. Mesh VSAT is a partial substitute for SMDS; therefore, greater acceptance of SMDS implies a lower market share for mesh VSAT.

As the most advanced and versatile application, BISDN has significant effects on all other applications. BISDN will be a highly competitive alternative to frame relay, SMDS, BISDN, and mesh VSAT. Availability of BISDN's advanced features and high bandwidth will lead to replacement of frame relay and SMDS applications. The versatility of BISDN may also reduce the prospective market for mesh VSAT systems after the year 2000.

Increased use of BISDN will also have an inverse effect on DBS use. The substitution relationship here depends on whether regulators will permit LECs to offer video on demand. It also depends on the rate at which LECs replace residential local loops with fiber optic cable. If residential subscriber lines can support video, and if LECs are permitted to provide it, BISDN can offer video service that is more convenient than any of its alternatives.

BISDN is complementary to two applications: mobile services and integrated video. The availability of BISDN may promote use of mobile data services. And the high and variable bandwidth of BISDN will probably promote acceptance of integrated video by cutting costs and increasing transparency.

Greater commercial success by mesh VSAT services will reduce terrestrial carriers' shares of broadband services traffic among closed user communities. Wide acceptance of DBS may limit the role of BISDN in home video delivery. Mobile data services may increase domestic traffic, boosting demand for BISDN. This effect will not be pronounced for the other broadband services because it will take time for mobile data innovations to gain acceptance and mature. BISDN will probably be the primary application by the time mobile data is a significant source of demand, and thus will be the primary beneficiary of any new mobile data traffic. User acceptance of integrated video will stimulate demand for BISDN, because BISDN is the application best suited to two-way video transmission for an open user community. Increased acceptance of integrated video will also stimulate demand for mesh VSAT capacity, particularly if mesh VSAT is less expensive than terrestrial transmission. Integrated video's stimulative effect on VSAT will probably decline in importance in the later years of the forecast horizon. Integrated video will no longer stimulate VSAT use when video terminals become sufficiently ubiquitous. As more people acquire video terminals, video users will benefit more from services that do not restrict them to a closed user community.

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1.0 INTRODUCTION

1.1 BACKGROUND

The mission of the National Aeronautics and Space Administration's (NASA) communications programs is to develop advanced, high-risk telecommunications technologies that fall outside the sponsorship capability of the private sector. Pursuit of this mission has two potential benefits. First, the Government makes investments that enable the United States to exploit advanced technologies in the commercial aerospace industry. Second, NASA gains communications capabilities that increase the productivity of future NASA missions.

The major thrust of the NASA Communications Program is development of the high-risk advanced communications satellite technologies needed to develop satellite systems with significantly enhanced capabilities. The program focuses on generally applicable technologies that provide new functions and capabilities to a broad range of applications, including the following:

- Multibeam spacecraft antennas
- Onboard switching and processing
- RF devices and components
- Advanced earth stations.

The program also determines whether systems are ready for implementation in operational systems. To ensure that useful technologies and systems are produced, NASA must anticipate future telecommunications user needs and technology enhancements. For this purpose, NASA has sponsored market forecast studies in the past.

Under NASA sponsorship, International Telephone and Telegraph Co. (IT&T) and Western Union performed market studies that assessed the status and trends of satellite markets. These studies forecast satellite markets to the year 2000. The results of these studies were used to define concepts for the early operational Advanced Communications Technology Satellite (ACTS), which led to the current experimental ACTS configuration. More recently, NASA undertook to integrate these results with the assessments of other studies. The result was an adjusted market estimate incorporating the effects of deregulation and the success of optical fiber.

Major new trends and forces are now shaping the communications industry. Examples of these trends include the following:

- Fiber optic systems
- The Integrated Services Digital Network (ISDN)
- Refinement of regulatory strategies following the divestiture of the American Telephone and Telegraph Company (AT&T)
- The overlap of geographically defined competitive arenas.

The emergence of new technologies and delivery systems has greatly changed the outlook for telecommunications services and their delivery. New types of networks are emerging. Local networks and long-distance networks are affected. New types of satellite networks are emerging. Fiber optics investment in both long-haul and local networks will allow vastly increased circuit capacities and signals of greater bandwidth. VSAT networks that transmit data via satellite direct to the user are being implemented to offer much greater flexibility, higher bandwidth, and lower service costs than the local terrestrial network can deliver. Networks and services are tending toward greater integration, providing greatly increased connectivity on a potentially global scale. Domestic and international satellite, domestic fiber optic systems, undersea cables, and all other media could ultimately coalesce into an integrated network permitting transmission from any location to any other location, mobile or fixed. Continued application of new space and terrestrial technologies are needed to enable these systems and to maintain the competitive position of the U.S. industry in telecommunications worldwide.

NASA is now developing technologies with the potential to change the relative cost of satellite and terrestrial communications. The benefits of these new technologies take two forms. First, economies of scale can reduce transmission cost per unit of data or distance. Second, economies of scope can make it easier for providers to "customize" service by automating the provision of many different services adapted to specific needs. The ACTS program is testing three primary kinds of innovations: fast-hopping spot beams, on-board processing, and Ka-band frequencies.

1.2 PURPOSE

This study updates and extends the previous forecast studies cited in section 1.1. The optical fiber infrastructure has become much more pervasive than foreseen in those studies. Narrowband ISDN, with a basic access of 144 kb/s, was included as an expected application but the emergence of BISDN, with a basic access of 155 Mb/s, was not. SMDS is a wideband service proposed by Bellcore that would support wideband, fast packet communications and enable user-configurable virtual networks. SMDS is viewed by some as a precursor to BISDN, which is expected to be deployed by 1995.

The purpose of this study is to help the NASA communications programs pursue the most appropriate satellite technology developments, based on current market and technological developments. To achieve this purpose, it is necessary to define the likely future communications service needs and requirements. Because of the dynamic character of the telecommunications industry and its markets, this type of requirements assessment needs to be updated periodically.

The significance of this study stems from NASA's role in driving advanced technologies that contribute to both transportation and communications. NASA assumes this role because of the risk involved in aerospace research and development. Lewis Research Center is responsible for the success of the Advanced Communications Program—it seeds industry with innovations that lower the cost and expand the capability of communications services. NASA programs also benefit from these technological advances. Enhanced communications capabilities have potential to improve the productivity of all NASA programs.

Communications satellite technologies have unique economic features that reward public sector involvement. All communications technologies have high fixed costs—an infrastructure must be installed and maintained at a relatively constant level, regardless of variations in demand. This subjects communications suppliers to the risk of changing capacity utilization and revenue per dollar of investment.

Satellite communications inject additional risks. The investment required is almost entirely "up front." Substantially all investment resources must be committed and financed before any revenue is generated.

Although satellite communications can be much less capital intensive than terrestrial communications, the capital required depends on one, or perhaps two, launch vehicles with a significant probability of failure, and one or two satellites that are difficult to repair in case of malfunction. This risk translates directly into an additional cost for a satellite operator—insurance is a major initial cost.

These risks boost the required cost of financing, which is why NASA is needed. By absorbing the further risk of research and development, NASA can disseminate relatively mature technologies that no for-profit entity could develop alone.

1.3 SCOPE

This study assesses the U.S. domestic market for voice, data and video services, including that portion of U.S. traffic destined for international transmission. The study estimates demand for these services in terms of overall magnitude and other characteristics. The forecast horizon of this study is the period 1991 through 2011.

The procedure followed in this study is to assess the status, plans, and capacity of the U.S. domestic communications infrastructure for comparison with the needs of several specific applications. This study estimates the market potential of these applications and the potential market share of satellite technology in each.

This effort to size and describe the satellite market must recognize not just technological capabilities, but the extent to which these capabilities can be made relevant to user needs. Conventional analyses of telecommunications markets focus on economies of scale—unit bandwidth cost of a given technology or breakeven distances for competing transmission media. Increasingly, communications technologies will succeed or fail to the extent that they exploit economies of scope—the ability of an investment or technology to adapt to diverse and rapidly changing user needs.

This analysis is based on the premise that competition on the basis of economics will shift over time toward a race to conform more closely with users' needs. For this reason, it will be impossible to assess satellite's competitiveness over the next 20 years without forecasting both technological capabilities and user requirements in descriptive and qualitative terms. Service integration will repeatedly shift the field of competition throughout the forecast time horizon. This market assessment will make critical qualitative judgments about the origin and timing of these shifts.

1.4 ORGANIZATION

This report is organized to trace the sequence of subtasks into which this study is divided. Section 2 describes an analysis of voice, video, and data traffic types, volume, and trends. Section 3 describes the principal factors that will affect the U.S. communications infrastructure between 1991 and 2011, to permit high-level forecasts of the future mix of transmission technologies that will be available to serve the traffic estimated in section 2. Section 4 identifies, segments, and describes applications that will use significant portions of the transmission capacity projected in section 3. Each of these applications is examined in section 5 to assess the potential of satellite technology to meet the needs of specific types of users. From the market segments identified as potentially addressable in section 5, section 6 identifies the market segments in which satellite has the best chance of capturing business from other technologies. Section 7 summarizes the conclusions of this study.

2.0 GENERAL COMMUNICATIONS TRAFFIC TYPES, VOLUME, AND TRENDS

Subtask one describes general communications traffic types, volume, and trends. As described in the statement of work, this section of the study has two purposes: identify the current traffic volume of voice, data, and video services, and perform temporal and demographic assessments to identify trends and forecasts of these trends to the year 2011. This subtask is intended to supplement forecasts made in previous NASA studies, incorporate the expected effects of new technologies, and update estimates of the significant trends in voice, data, and video traffic.

2.1 OVERVIEW

This section describes the previous satellite market studies performed for NASA, Booz·Allen's approach to projecting traffic demand, and a summary of the techniques used in forecasting demand.

2.1.1 Background

In 1979, IT&T assessed demand for 30/20 GHz fixed communications by distinguishing market segments that required different forecasting techniques (IT&T, U.S. Telephone and Telegraph Corp. 1979, vol. 2), as shown in figure 2-1. In 1983, NASA sponsored two studies of the status and trends of satellite markets:

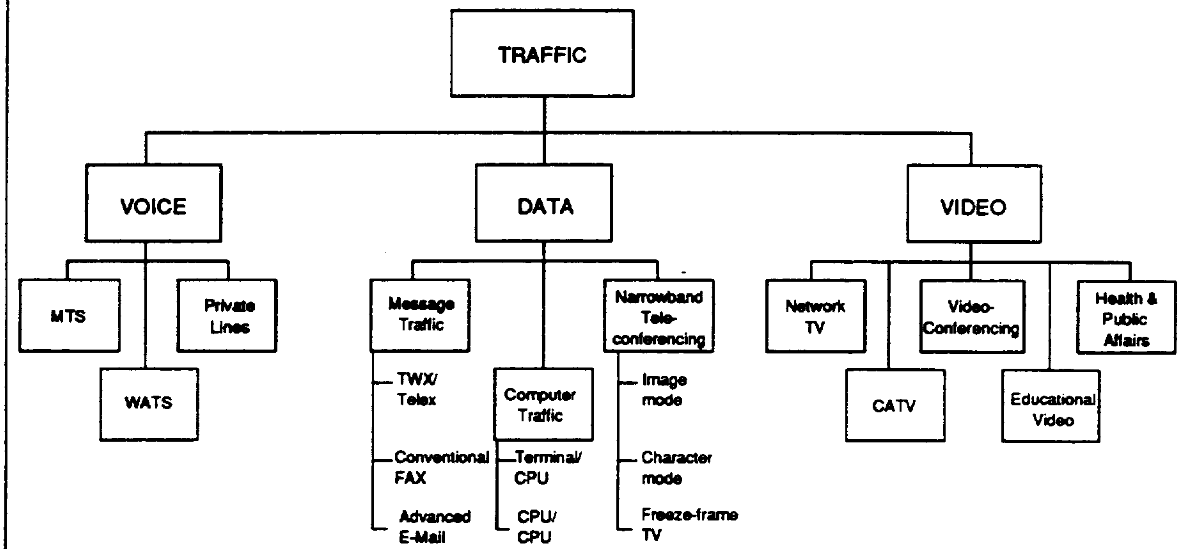
- IT&T, "Customer Premises Services Market Assessment" (IT&T, U.S. Telephone and Telegraph Corp. 1983, vol. 2)
- Western Union, "Satellite Provided Fixed Communication Services: A Forecast of Potential Domestic Demand Through The Year 2000." (Western Union 1983, vol. 2)

In its Customer Premises Services Market Demand Assessment, IT&T subdivided demand into high-level, technology-based categories, as shown in figure 2-2. Western Union subdivided demand with a more detailed, application-oriented approach, as shown in figure 2-3.

2.1.2 Approach to Projecting the Demand for Telecommunications Traffic

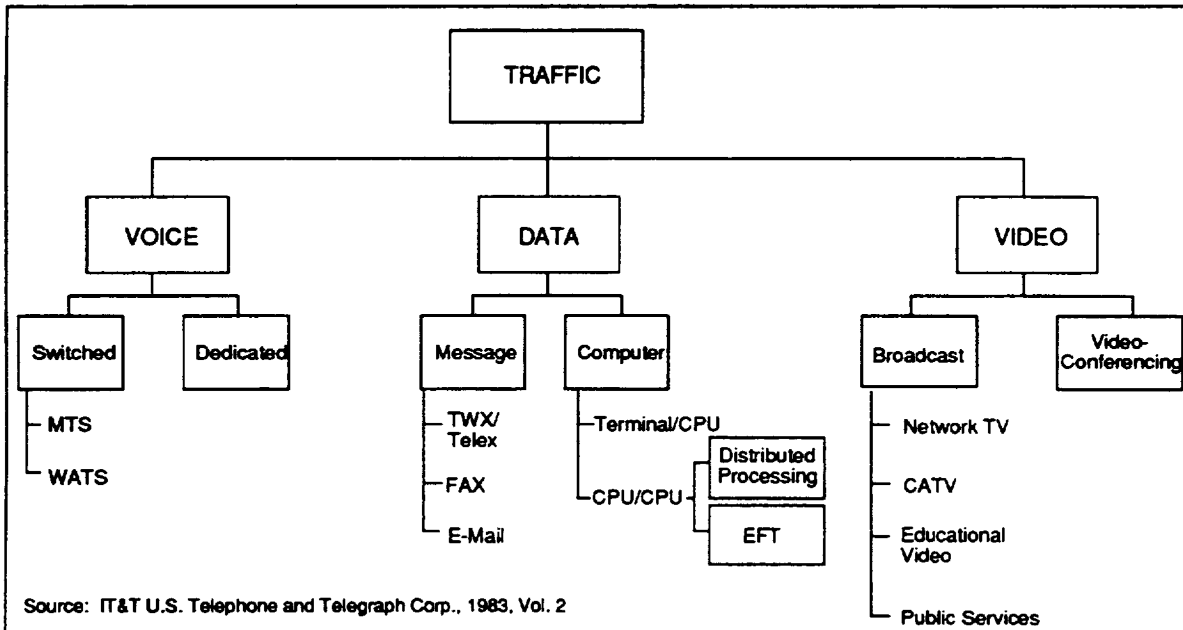
There are several steps in our approach to projecting the demand for telecommunications traffic. This process is shown in figure 2-4. Our first step in defining the market for voice, data, and video services was background research. This stage consisted of reviewing previous NASA studies, examining related technical articles, and defining preliminary application areas for voice, data, and video projections. The next two steps of the process, raw data gathering and market research, were done in concert and laid the groundwork for the traffic projections. The next stage of the process relied on the expertise of Booz·Allen personnel, outside consultants, and industry experts to shape our projections of telecommunications traffic. Baseline traffic projections were made using the collected raw data, market trends, and several forecasting techniques. Additional factors that may have an effect on the growth of the individual traffic categories were used to obtain our final adjusted projections of traffic for the 1991 to 2011 time frame.

FIGURE 2-1
1979 IT&T Study Market Segments



Source: IT&T U.S. Telephone and Telegraph Corp., 1979, Vol. 2

FIGURE 2-2
1983 IT&T Study Market Segments



Source: IT&T U.S. Telephone and Telegraph Corp., 1983, Vol. 2

FIGURE 2-3
1983 Western Union Study Market Segments

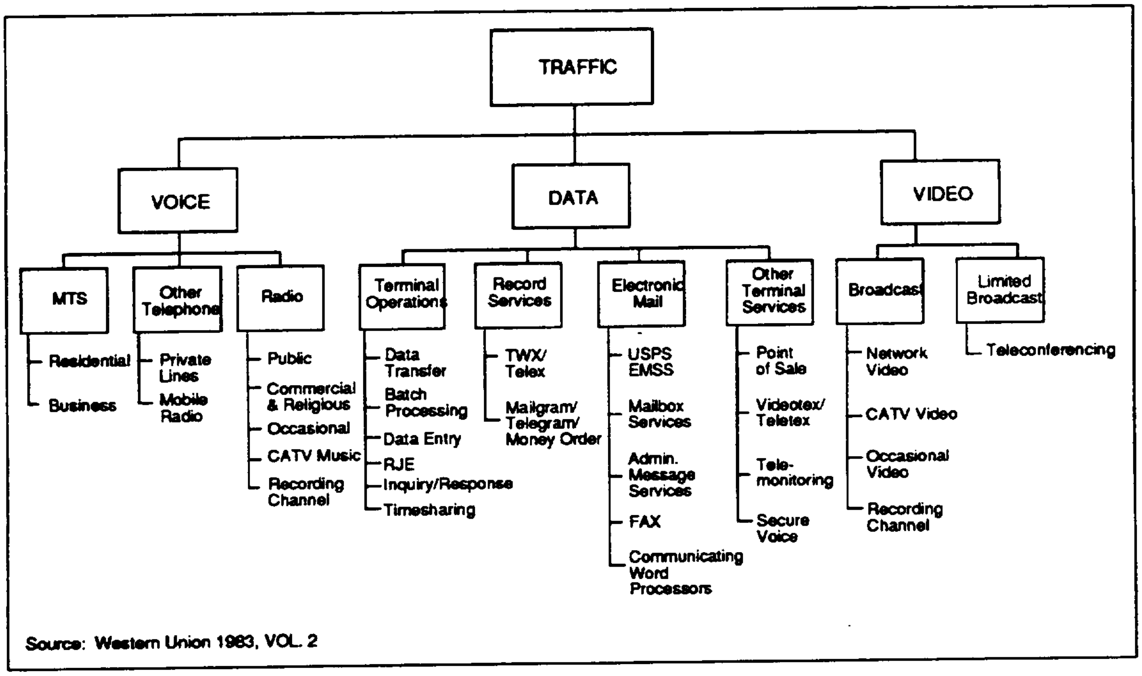
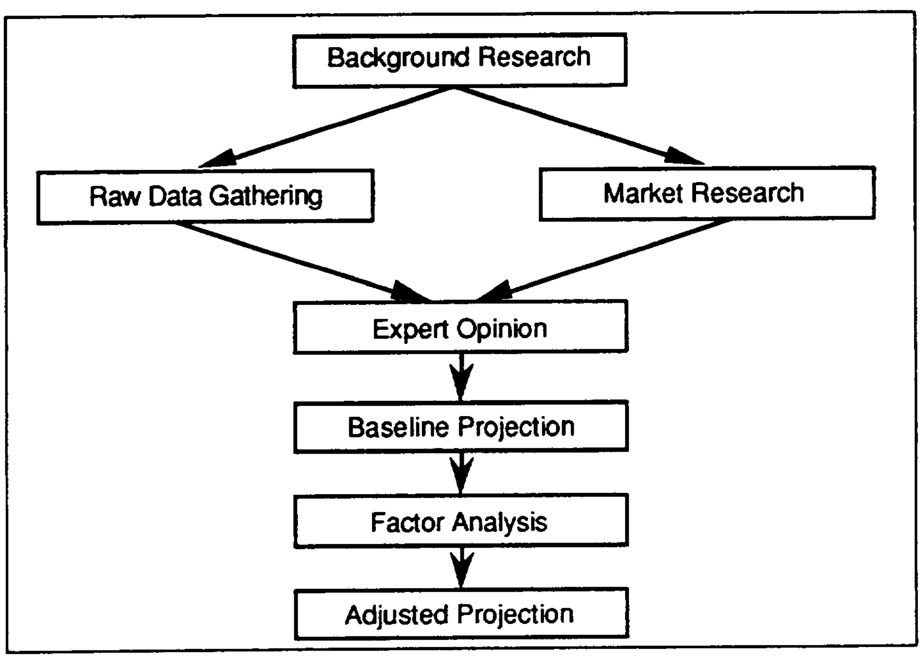


FIGURE 2-4
Approach to Demand Projection



The Method of Decomposition (Armstrong 1978) was used to obtain adjusted projections. This method consists of defining the trends that affect future growth—making them as independent of each other as possible—and estimating the magnitude and time period for each of these trends. Armstrong shows that this method produces more reliable estimates than an approach that tries to estimate future changes in toto.

The estimates of magnitude and duration of the trends result from judgments, necessarily subjective, by Booz·Allen and external experts. Except where otherwise identified, these estimates were made by Booz·Allen on the basis of the trends discussed in the literature and interviews with industry experts. Often, these sources gave comparative judgments (e.g., that trend A will be more significant than trend B) rather than absolute numbers and sometimes sources differed among themselves on magnitude or duration of a trend. In all cases, the estimates selected were examined for internal consistency and reasonableness by Booz·Allen staff and sometimes reviewed with outside experts to assure that there were no egregious flaws.

The method of calculating adjusted predictions can be explained by a numerical example. Suppose that the baseline predictions for a particular service were 100 units in 1991 and 150 in 1996. This represents an 8.45 percent per year compounded growth. Suppose that factor analysis suggested increases of 2 percent per year for this whole period and 1 percent per year for 1993-2005 and a decrease of 3 percent per year from 1991-1994. We add these various components linearly, giving the following changes to the baseline value for 1991:

- 1992: 7.45% above 1991
- 1993: 7.45% above 1992
- 1994: 8.45% above 1993
- 1995: 11.45% above 1994
- 1996: 11.45% above 1995.

These changes are then compounded to give an adjusted prediction of 155.5 units for 1996. For the next period, 1996-2001, the baseline annual growth is obtained as above from the baseline predictions. The annual growth factors for the 5 years are then calculated as above and applied to the adjusted prediction for 1996 to give the adjusted prediction for 2001, and so on for 2006 and 2011.

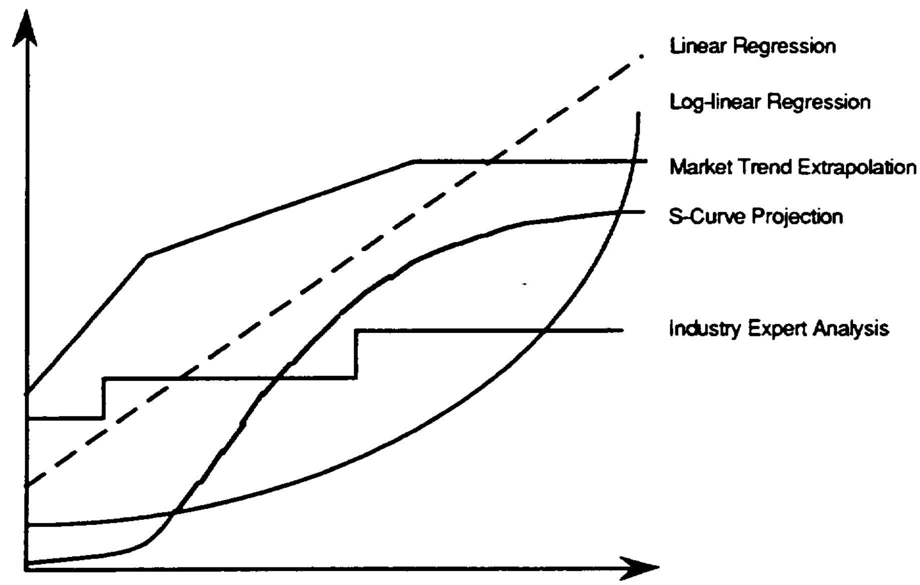
Because projections are inherently imprecise, the following rule was used for significant figures: Numbers whose first significant digit is 2 through 9 are rounded to 2 significant figures; numbers whose first significant digit is 1 are rounded to 3 significant figures, of which the third is 0 or 5.

2.1.3 Forecasting Techniques

Several forecasting techniques are used in projecting the future demand for voice, data, and video traffic volumes. The types of curves that result from using these techniques are shown in figure 2-5.

The techniques that are used in projecting traffic volumes are both quantitative and qualitative, generally reflecting the extent to which a forecast can be based strictly on historical data (Wheelwright 1980, 5). Quantitative methods such as linear and log-linear regression and to some extent, market trend extrapolation, follow a set of simple rules to develop a forecast of future

FIGURE 2-5
Forecasting Techniques



Source: Booz·Allen & Hamilton Inc.

values. Qualitative methods for our study include industry expert analysis and the use of s-curve projections. These methods are used when historical data are not available or accurate, when future traffic growth does not depend on previous growth, or when the traffic-generating application is at the beginning of its market or technology life cycle (Wheelwright 1980, 5). This is the reason that qualitative techniques are sometimes referred to as technology forecasting.

2.2 TRAFFIC TYPES

This study subdivides the demand for voice, data, and video into categories that will have the most significant impact on telecommunications traffic currently and through 2011. The specific categories and their relations are shown in figure 2-6. This set of categories is similar to those used by IT&T and Western Union, with modifications dictated by changes that have occurred in technologies and markets.

2.3 VOICE TRAFFIC

The voice category is divided into MTS and business voice. Figure 2-7 highlights the voice category and shows the segments of demand that make up this category. MTS is studied to assess the demand for regular long-distance voice calls over the public long-distance networks. The MTS category includes both residential and business applications. The Business Voice category includes all business voice applications other than MTS: private lines, private networks, 800 service (sometimes called inward Wide-AreaTelephone Service [WATS] [INWATS]), and 900 service.

FIGURE 2-6
Categories of Voice, Data, and Video Traffic

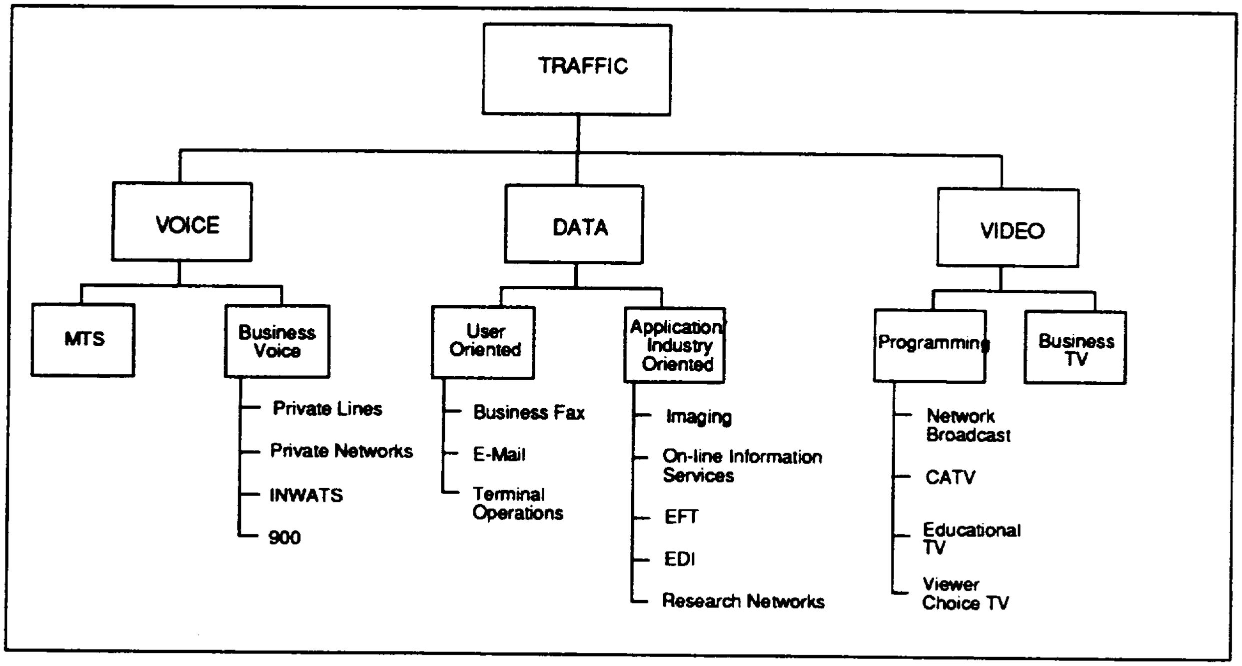
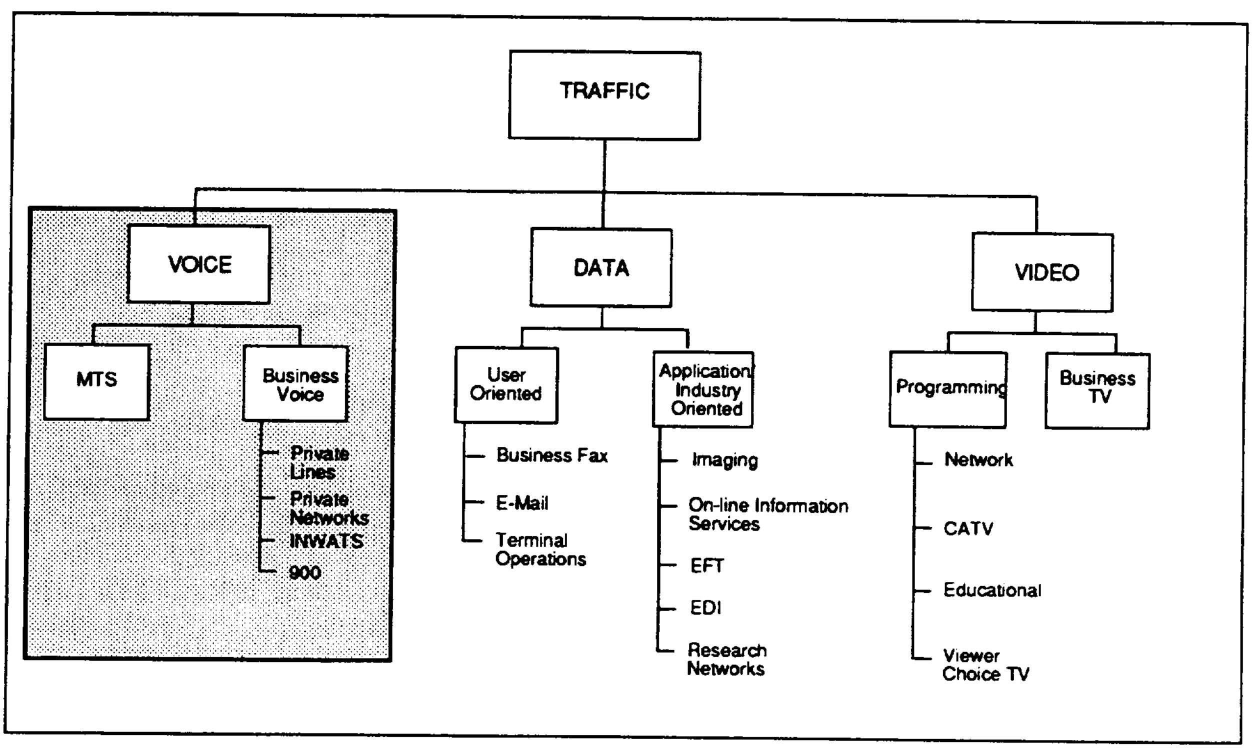


FIGURE 2-7
Voice Traffic Categories

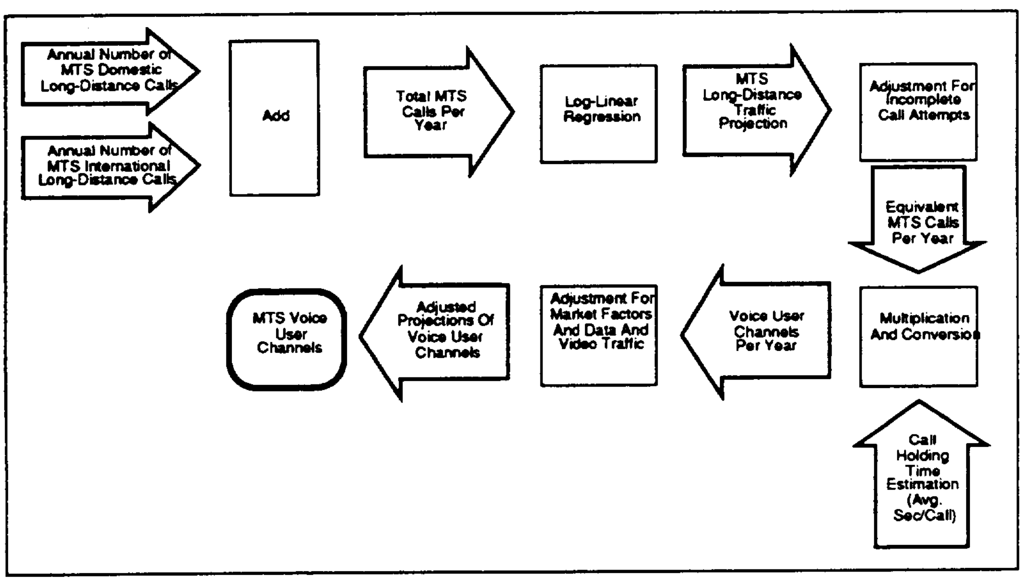


2.3.1 Message Telephone Service

MTS is defined for this report as inter-local access and transport area (LATA) switched voice-grade service. This service is provided by the interexchange carriers (IECs) to their customers on a dial-up basis. MTS serves both residential and business users. Voice calls made using MTS make up the largest component of demand assessed in this study. This is because MTS is the most general of the demand categories and includes most residential, coin-operated, and regular business services.

2.3.1.1 Method. The flow chart shown in figure 2-8 shows the steps taken in forecasting the demand for MTS voice traffic. There are two annual series of data that are used in the MTS traffic projection: total number of long-distance calls and number of international long-distance calls. The historical growth rates of these calls are used to extrapolate MTS traffic over the years of the study using log-linear regression. Adjustments are made for incomplete call attempts and call holding times to obtain projections of the total number of MTS call-seconds. These projections for 1991 to 2011 are then adjusted for market and technological factors that affect the growth of MTS traffic.

FIGURE 2-8
MTS Data Flow Diagram



2.3.1.2 Baseline Projection. AT&T's *The World's Telephones* (AT&T 1981-1990) and the Federal Communication Commission's (FCC) *Statistics of Communications Common Carriers* (FCC 1989/90) are used as the sources for historical data showing the number of domestic and international long-distance calls completed annually. These raw data are shown in figure 2-9.

The number of international telephone calls is included in the MTS traffic total because of the effect of the tail end of each international call. Because access to international telephone cables and satellites is through facilities located near the coasts and away from population centers, most international calls use IEC transmission facilities within the United States. For this reason, international telephone call statistics are bundled with long-distance calls in assessing the demand for MTS service.

FIGURE 2-9
MTS Calls Completed Per Year (Billions)

Domestic Long-Distance

Year	Calls Completed	Year	Calls Completed
1965	4.7	1978	15.2330
1966	5.2	1979	17.2000
1967	5.6	1980	19.7830
1968	6.2	1981	18.7700
1969	6.8	1982	36.5316
1970	7.2	1983	N/A
1971	8.0	1984	30.4915
1972	9.2	1985	37.5253
1973	9.9	1986	42.3208
1974	10.6	1987	51.7440
1975	11.5	1988	48.4569
1976	12.2	1989	48.9726
1977	13.5	1990	N/A

International Long-Distance

Year	Calls Completed	Percent of Total MTS
1982	0.2374	0.65
1983	N/A	N/A
1984	0.4276	1.38
1985	0.4117	1.09
1986	0.2884	0.68

Sources: AT&T and FCC

Several techniques can be used to forecast the demand for MTS voice calls. Because there are historical data going back to 1965 that show the growth of long-distance calls, linear regression techniques can be used. The total number of MTS calls is plotted in figure 2-10, showing a nearly constant growth rate of close to 11 percent. Similarly, international calls show a growth rate of about 7.3 percent per year. Using these figures, long-distance, international, and the combined number of MTS calls can be projected through 2011 (figure 2-11). The projected number of total MTS calls completed per year for the years 1991, 1996, 2001, 2006, and 2011 are displayed in the fourth column of figure 2-12.

FIGURE 2-10
Semi-Logarithmic Plot of MTS Growth

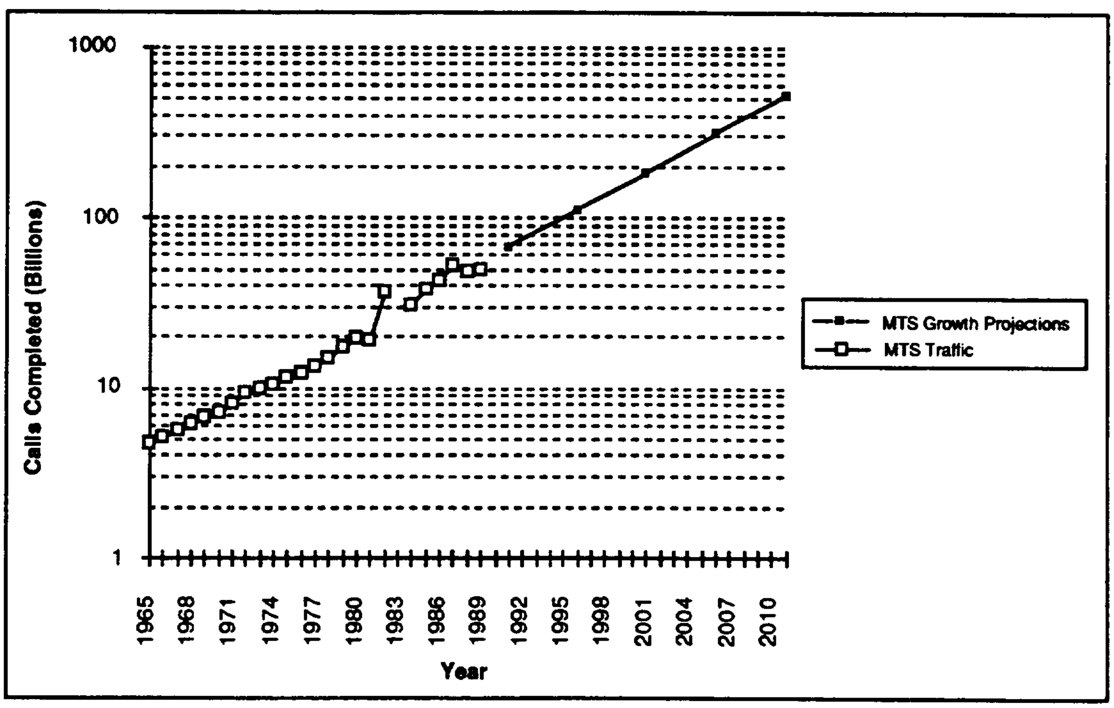


FIGURE 2-11
MTS Traffic Projections

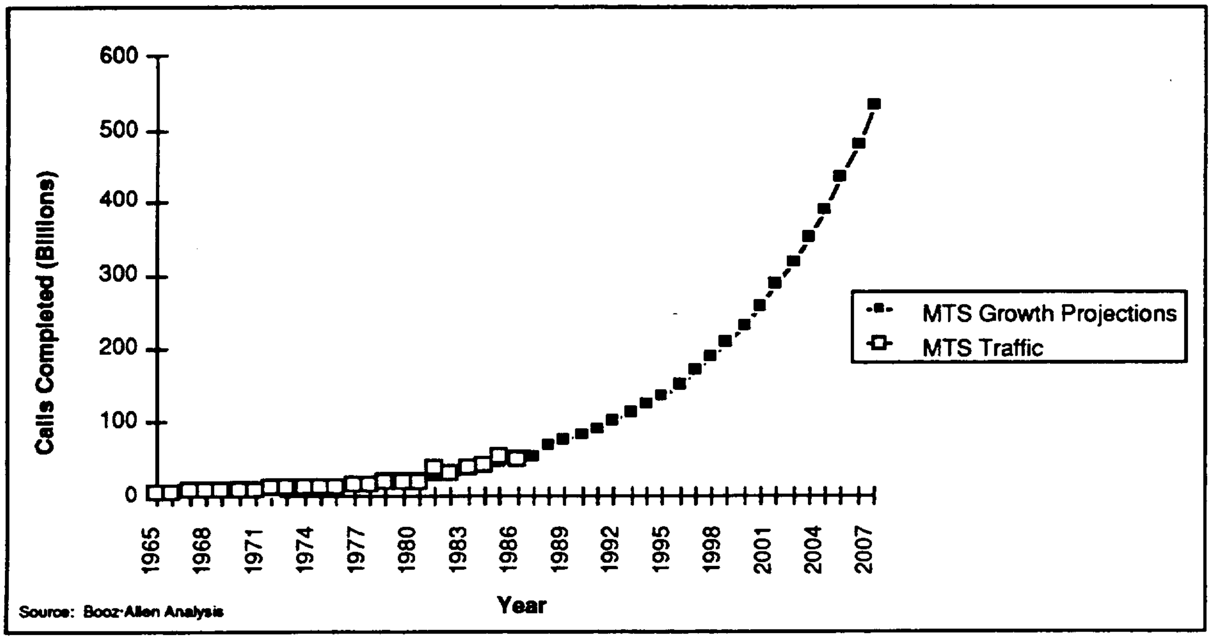


FIGURE 2-12
MTS Call-Seconds Conversion

Year	LD Calls Completed (10^9)	Int'l Calls Completed (10^9)	Total Calls Completed (10^9)	Equivalent Calls/Year (10^9)	Total Call-Seconds (10^{12})
1991	66	0.54	67	68	23
1996	110	0.77	110	110	37
2001	185	1.10	185	185	62
2006	310	1.55	310	310	105
2011	520	2.2	520	520	175

Source: Booz·Allen Analysis

Holding time estimates for completed inter-LATA calls were determined from the FCC's *Statistics of Communications Common Carriers*, (FCC 1989/1990). For both interstate and intrastate calls, the average holding times were 5.6 minutes. In earlier studies, holding time was assumed to increase over time because of such factors as the dependence of holding time on distance, the fraction of inter- and intrastate calls, and a historical trend toward longer holding times (IT&T, U.S. Telephone and Telegraph Corp. 1983, vol. 2). Many of these factors have changed since the previous studies were done. For example, IT&T found a negative correlation between distance and holding time, due to longer distance calls being more expensive. As long-distance rates have largely become postalized, distance sensitivity has become less of a factor in the pricing of MTS service. In addition, long-distance rates are probably at the level, in real dollars, that they will be in the future. For these reasons, our projections of MTS traffic assume a fixed holding time of 5.6 minutes.

Incomplete call attempts are not reflected in the number of calls reported by the FCC and AT&T, but have historically been a significant part of the total traffic. Previous studies, (IT&T, U.S. Telephone and Telegraph Corp. 1979; vol.2, IT&T, U.S. Telephone and Telegraph Corp. 1983, vol.2), adjusted call volume to account for the effect of misdialed calls, busy signals, and wrong numbers. Using 6 minutes as the holding time for completed calls and 45 seconds as the holding time for incomplete calls, their calculation was as follows:

Let x = number of calls completed
y = multiplier for x to adjust for incomplete calls.

y was used to scale up the number of complete calls at the same 6-minute holding time. Based on various sources, they found that about 70 percent of calls were completed. Therefore, the ratio of incomplete calls to complete calls was 3 to 7. The total time used is then:

$$360x + 45(3/7)x = 360y \text{ (seconds)}.$$

The first term is the time used for completed calls. The second term is the time used for incomplete calls. Solving for y/x gives 1.05, so they added 5 percent to the number of call-seconds used.

With the great decrease in post-dial delay due to nonhierarchical networks and common-channel signaling, a holding time for incomplete calls of 45 seconds is too long today. A better number would be 8 to 10 seconds, allowing time to distinguish between a ring and a busy signal. This does not account for wrong numbers, which would hold longer, but this traffic is probably a small fraction of the total. For 1996 and beyond, the introduction of Signaling System 7 (SS7) into the local exchange carrier (LEC) networks should decrease the holding even further, to about 5 seconds (Booz·Allen estimate). Repeating the IT&T calculation using these numbers and a holding time for completed calls of 336 seconds (5.6 minutes) and the same 70 to 30 ratio of completed calls to incompletes, we get factors of 1 percent for 1991 and 0.6 percent for 1996 and beyond. These factors are used to add to the projections of total calls completed to obtain equivalent calls per year in the fifth column of figure 2-12. The sixth column lists the projected number of MTS call-seconds for the study years 1991, 1996, 2001, 2006, and 2011.

2.3.1.3 Adjusted Projection. The 11 percent growth rate obtained using regression techniques reflects the significant growth in long-distance calling in the 1980's due to several market and technology factors. According to the FCC's 1991 report on long-distance market share (FCC

1989/90), this increase in long-distance calling stems from overall economic growth, price reductions, and extensive advertising.

Toward the end of the 1980's, statistics reported by the interexchange carriers and the FCC show a much slower growth, and even a decrease in long-distance calling (figure 2-9). This decrease in MTS growth is tied to the factors that spurred growth in the 1980's that may have less of an influence in the 1990's and that may have no effect after the year 2000. During the 1991 to 2011 study period, there will be new factors that will affect the growth of MTS traffic. Our adjustment methodology takes into account these factors by adding and subtracting quantitative estimates of the percentage effects of these factors on the projected traffic. Factors that are addressed include:

- Elimination of local cross-subsidies
- Market saturation
- Less price competition
- New technologies (cellular, Personal Communications Network [PCN]).

These factors are discussed in the following paragraphs.

Some of the factors that are discussed are used to subtract percentages from the baseline growth rate. This is because these factors included in the baseline growth rate have less of an effect or no effect on the future MTS growth. One of the factors that led to a decrease in prices, but no longer has an effect on the growth of MTS, is the elimination of the subsidization of local telephone rates by long-distance rates. This factor is taken into account in the adjusted projection by subtracting a 2 percent growth from the baseline projection.

One of the factors that spurred the growth of long-distance calls in the 1980's was the breakup of AT&T and the growth of the competitive long-distance marketplace that developed after deregulation. The price of long-distance calls decreased during this period due to competition between the major interexchange carriers. This drop in prices and increase in the marketing of long-distance services may have been a factor in the growth of MTS calls during the 1980's and is reflected in the baseline projections. To account for the declining effect of price competition on the growth of MTS, 2 percent is subtracted from the baseline growth rate for the duration of the study (1991 to 2011).

Market saturation is a factor that affects the growth of total long-distance calls. Some of the growth in calls during the 1970's and 1980's can be attributed to the connection of long-distance service for new customers and the introduction of new services and billing options for old customers. The growth in MTS calls due to this service growth becomes negligible when these new service options do not add any new calls to the total, but only replace an old service that was already contributing traffic to the long-distance network. A 2 percent decrease is used as an estimate of market saturation effects on the baseline growth.

New technologies are expected to continue affecting the growth of MTS calls. Fiber optic networks have already allowed the IECs to lower prices on long-distance service. In addition, new technology, such as cellular phone service and PCN, are expected to increase the growth of MTS over the course of the study. As customers have more access to telephones, they tend to use them more. This has been the case with cellular phones, allowing people to make calls when they are out of the office and the home, therefore adding to the total long-distance calling volume. The success of PCN, similar to cellular service, would add additional traffic to the long-distance networks. A 1 percent increase over the baseline is estimated for cellular for the years 1991 to 2000, and 3 percent is added to the baseline for the effect of PCN, from 2000 to 2011.

The factors that have been discussed in this section are summarized in figure 2-13. These factors are used to adjust the baseline projection of MTS calls. Figure 2-14 shows the relationship between the factors, the adjusted projections, and the baseline projections. Figure 2-15 shows the adjusted number of call-seconds calculated from the adjusted call projections.

FIGURE 2-13
Summary of MTS Factors

Factor	Effect on Baseline Projections	Duration of Effect
End of Phase Out of Local Cross-Subsidies	- 2%	1991 - 2011
Less Price Competition	- 2%	1991 - 2011
Market Saturation	- 2%	1991 - 2011
New Technology - Cellular	+ 1%	1991 - 2000
New Technology - PCN	+ 3%	2000 - 2011

Source: Booz·Allen Analysis

2.3.1.4 Notes. The growth of MTS traffic can also be examined on the basis of switched access minutes handled by the long-distance carriers. Switched access minutes are those minutes transmitted by the interexchange carriers that also use the distribution networks of local telephone companies. This traffic includes ordinary long-distance and the open end of WATS-like calls, and excludes calls on private telecommunications systems, leased lines, and minutes on the closed end of WATS (FCC 1991a).

According to a press release accompanying the FCC's 1991 report on the long-distance market, "The total number of interstate switched access minutes handled by all long distance carriers has grown rapidly since mid-1984 — at a rate averaging more than 12 percent even though growth rates slowed in 1990" (FCC 1991b). This growth rate for switched access minutes is comparable with our growth rate of almost 11 percent for completed calls.

2.3.2 Business Voice

Voice services other than MTS are grouped into the Business Voice category. This category contains services typically offered by the IECs to business, government, and institutional users. Business Voice includes private lines, private networks, 800 service (INWATS), and 900 service.

2.3.3 Private Lines

Private lines are digital or analog lines leased from IECs for point-to-point high-volume communication or for use as a component in private corporate networks. Analog transmission is usually leased on a dedicated basis. Digital transmission services consist of Digital Data Services (DDS), Fractional T1 (FT1), T1, T3, and other higher bandwidth services.

FIGURE 2-14
Adjusted MTS Growth

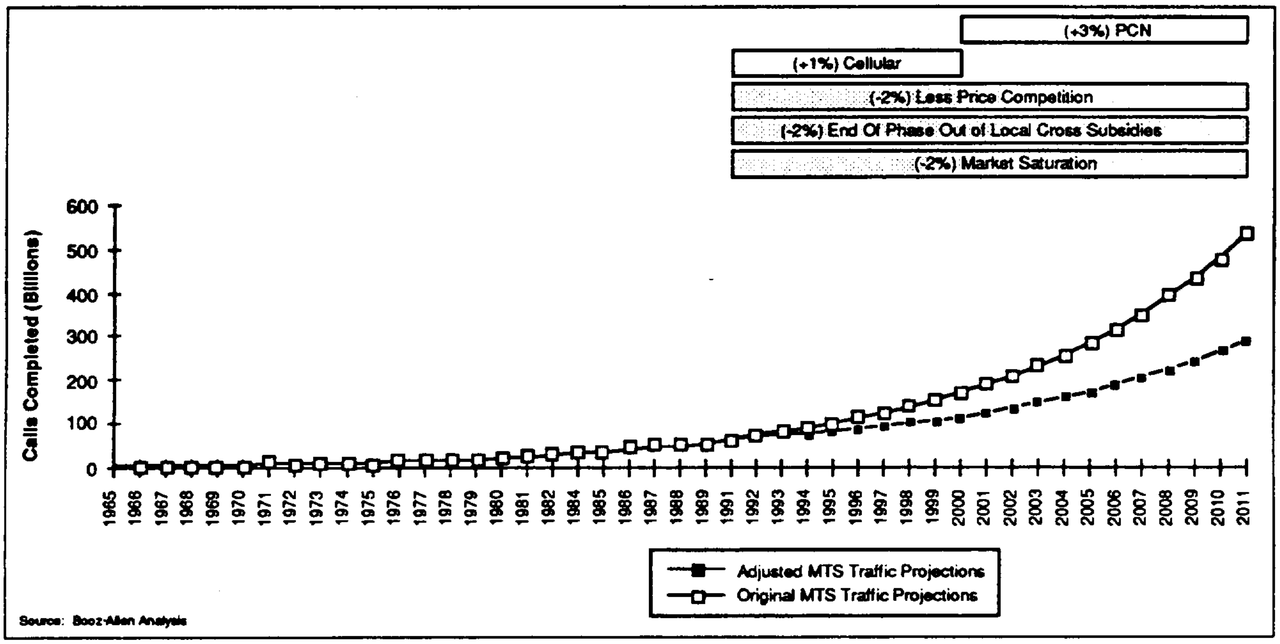


FIGURE 2-15
Adjusted MTS Projections

Year	LD Calls Completed (10^9)	Int'l Calls Completed (10^9)	Total Calls Completed (10^9)	Equivalent Calls/Year (10^9)	Total Call-Seconds (10^{12})
1991	66	0.54	67	68	23
1996	88	0.77	89	90	30
2001	120	1.10	120	120	40
2006	175	1.55	175	175	59
2011	260	2.2	260	260	87

Source: Booz·Allen Analysis

The use of private lines and private networks have changed over the last few decades. Figure 2-16 lists the major trends of the 1970's, 1980's, and 1990's (Zerbiec 1991, 25: 33-36)

FIGURE 2-16
Trends in Private Lines and Private Networking

1970's	• Before divestiture, corporate networking services were provided by AT&T. • Corporate users had a difficult time obtaining custom services.
1980's	• AT&T divested and alternate providers of long-distance service emerged. • Network managers had numerous private lines and service options for building their own customer corporate networks. • New technology emerged: digital transmission, multiplexing, analog compression. • Data traffic emerged as a driving force in corporate network decision making.
1990's	• Telephone companies offer Virtual Network Services as a means of providing additional full-service solutions to the corporate user. • The market for T1 and T3 private lines is strong and carriers introduce fractional T1 and switched T1 service as competition over market share continues.

Source: Zerbiec 1991

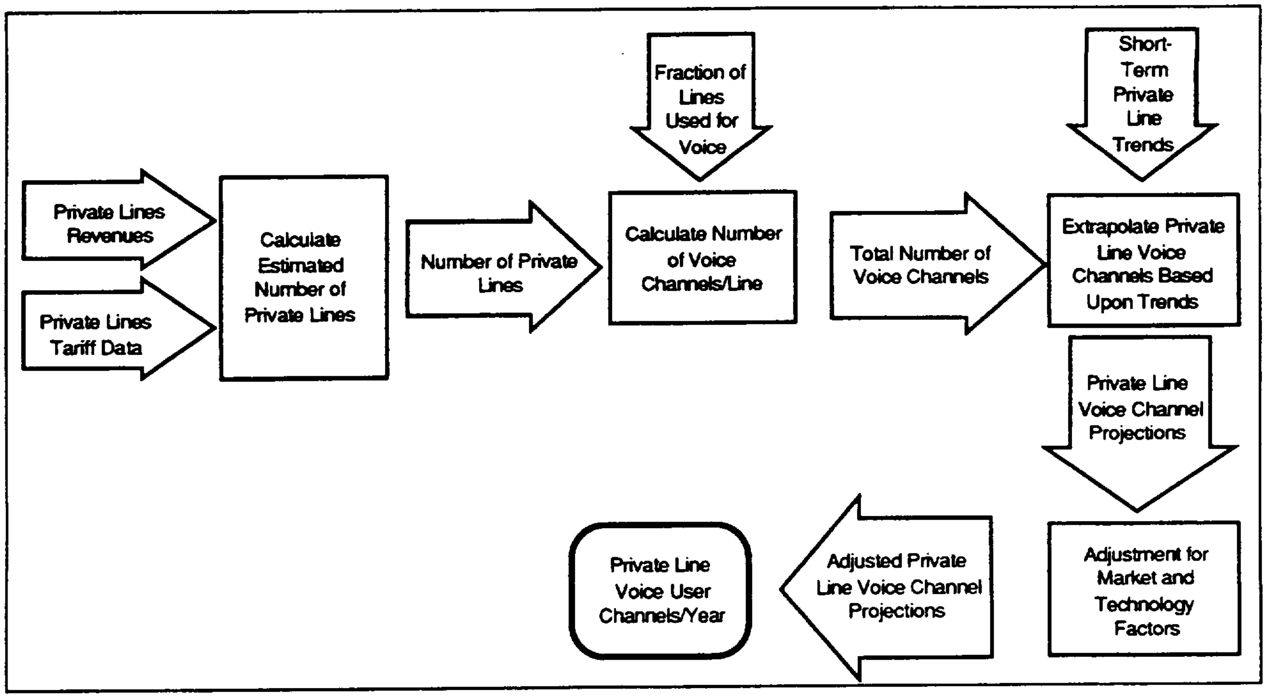
Private lines offered by the IECs can be divided into analog and digital services. Digital service can be divided into the following categories:

- DDS
- DS0 voice-band
- T1
- T3
- FT1.

DDS offers all-digital transmission facilities with data transmission rates up to 56 kb/s and accommodates high data throughput and low error rates. DS0 voice-band offers digital voice and data transmission at speeds of 56 to 64 kb/s. T1 and T3 are digital transmission private lines supporting 1.544 Mb/s and 44.736 Mb/s, respectively. FT1 is a service offered by splitting off and leasing segments of a T1 line in multiples of 64 kb/s (1 DS0 channel).

2.3.3.1 Method. The flow chart shown in figure 2-17 summarizes the steps taken in forecasting the demand for voice traffic carried by private lines. Carrier revenues, tariff data, and industry market trends are used to project the future private line voice traffic demand. Industry trends and projections have been collected that describe the market for private lines. This market is becoming increasingly dominated by data services, but a large percentage of private line traffic is still voice. Private line revenue and tariff listings provide the raw data for private line voice traffic projections. From the raw data, the estimated number of 1991 private lines are calculated. The number of voice channels that these private lines represent are extrapolated based upon industry trends. These baseline voice channel projections are then adjusted for market and technology factors that may affect future growth.

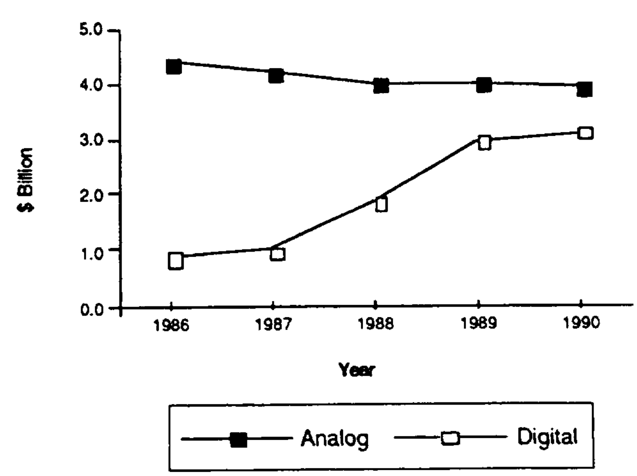
FIGURE 2-17
Private Lines Data Flow Diagram



2.3.3.2 Baseline Projection. The private line market is divided into digital and analog services. Figure 2-18 shows historical revenue estimates for both markets for the 1986 to 1990 time frame (Dataquest 1991). These figures are Dataquest estimates of long-distance service revenues. The trends show the increase in digital service revenues and the decrease in analog service revenues as data applications demand more network bandwidth and the demand for voice services are being handled by digital lines.

FIGURE 2-18
Analog and Digital Private Line Revenues

Year	Analog	Digital
1986	$4.4	$0.9
1987	4.2	1.0
1988	4.0	1.9
1989	4.0	2.9
1990	3.9	3.1



Source: Dataquest 1991

Figures 2-19 and 2-20 show additional private line market revenue estimates and projections. Figure 2-19 shows growth in FT1, T1, and T3 markets and a corresponding decline in the DDS and voice-grade markets (The Yankee Group 1991, 25:16). Figure 2-20 shows another view of the FT1, T1, and T3 markets (Data Pro Info Services Group 1991, Data Communications 1989). Note that these two projections start at the same levels in 1989 but diverge widely by 1993.

FIGURE 2-19
Private Line Market Revenue Estimates and Projections

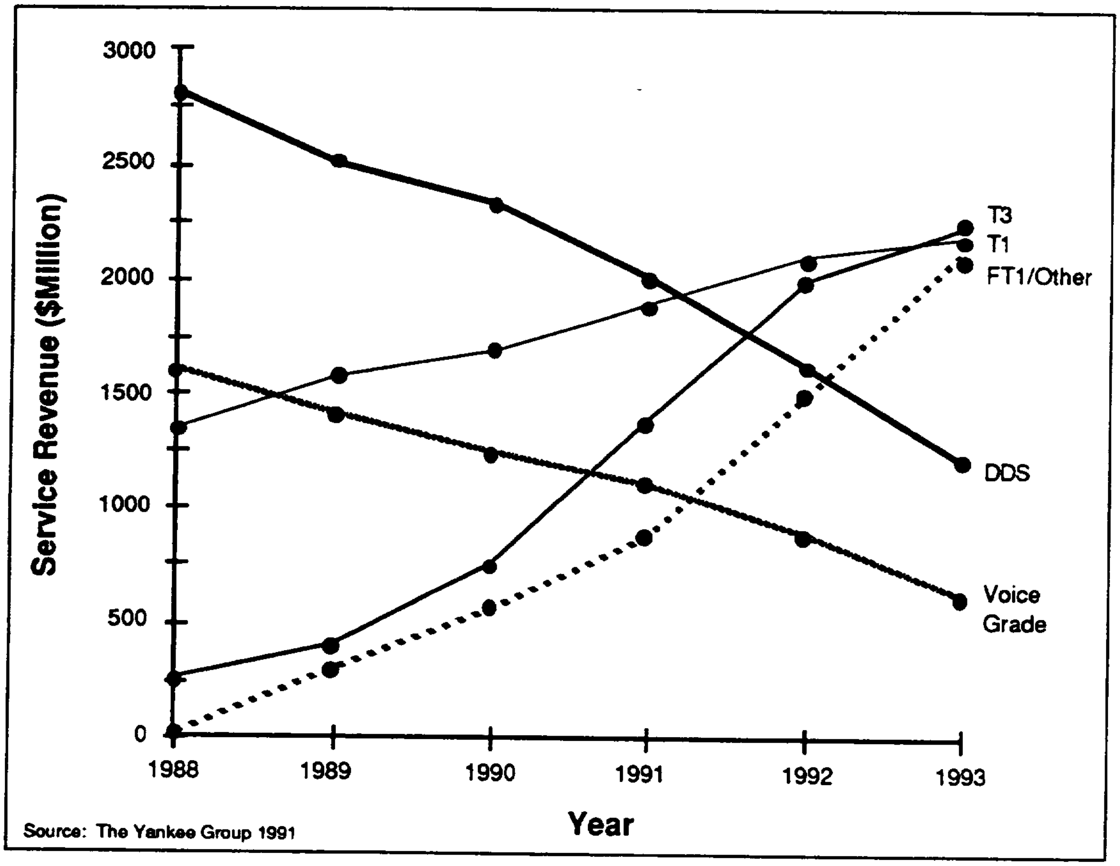
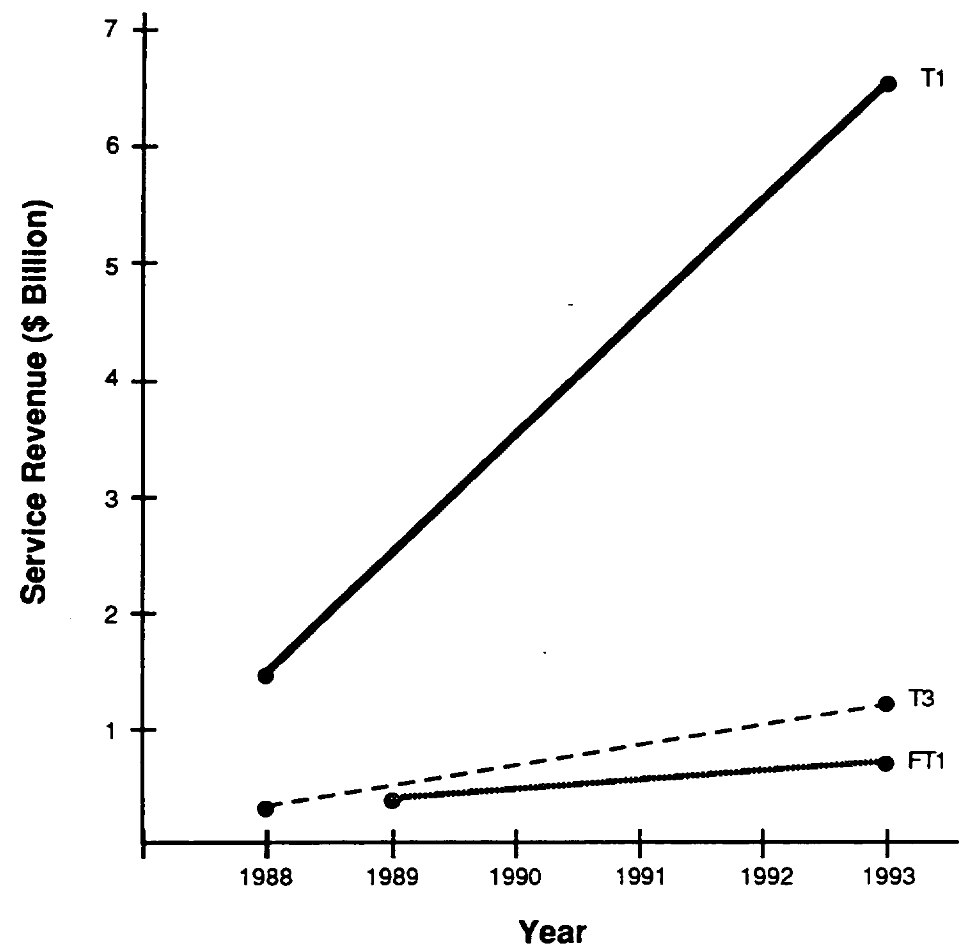


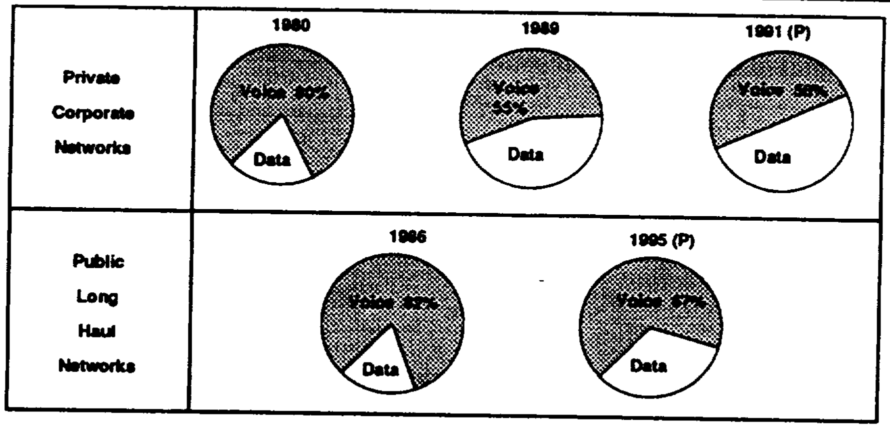
FIGURE 2-20
T1, T3, and FT1 Market Revenue Estimates and Projections



Sources: Data Pro Info Services Group, 1991; Data Communications 1989

Because of the increase in demand for new types of data services, largely created by a new generation of bursty computer-generated traffic, users have been demanding high capacity, flexible digital pipelines from their telecommunications providers. These providers have responded by increasing the availability of T1, T3, higher-bandwidth data channels, fractional T1s and T3s, switched high-speed digital circuits, and other integrated services (Zerbiec 1991, 25: 33-36). Correspondingly, much of the growth in the private line market can be attributed to data-generating applications. These corporate network usage trends indicate that data traffic is growing as a percentage of total private line usage. Figure 2-21 shows this growth in private corporate networks and in the public switched network.

FIGURE 2-21
Data Traffic Percentage Growth



Source: Zarbiec 1991

Private lines carry voice, data, and video. To estimate demand for voice communications over private lines and networks, this traffic must be segmented. Of the private line services that have been discussed, the analog voice-grade, FT1, T1, and T3 services all carry voice traffic. DS0 circuits are assumed to be used for data. Obtaining raw data from the IECs on the number of private lines leased is difficult; therefore, estimates must be made based upon publicly available data. For each of the private line services that are applicable to voice traffic, dividing estimated 1989 inter-LATA revenues (Data Pro Info. Services Group 1991, Data Communications 1989) by representative costs per line yields an estimated number of private lines. Each of these services carries a different number and percentage of voice channels. These factors are taken into account in Figure 2-22. Column 2 lists estimated industry revenues. Representative costs are based on 175-mile private line costs using AT&T rates except for the T3 line, which is based on MCI rates. Column 3 lists representative costs per private line per year. These costs were obtained from published IEC rates listed in the CCMI *Guide to Networking Services — InterLATA Telecommunications Rates and Service*. For FT1, we assumed a 384 kb/s line priced at 4 times the rate for an analog voice-grade circuit. The estimated number of private lines result from dividing revenues by costs. Column five lists the estimated percentage voice carried by each type of private line. For analog voice-grade service, almost all of the traffic is voice, while for the other types of lines a 50 percent voice to data ratio is used. This ratio is based upon the data presented in figure 2-21 for private corporate networks. Given the number of available voice channels per type of private line listed in column 6, the number of voice channels for private lines is calculated. This figure is used as a starting point in establishing a baseline growth and voice channel projection for private lines.

Because there are not enough historical data to support a rigorous regression analysis, industry estimates of private lines market growth must be used to make a baseline traffic projection for the target years of the study.

FIGURE 2-22
Private Line Voice Channel Estimates for 1989

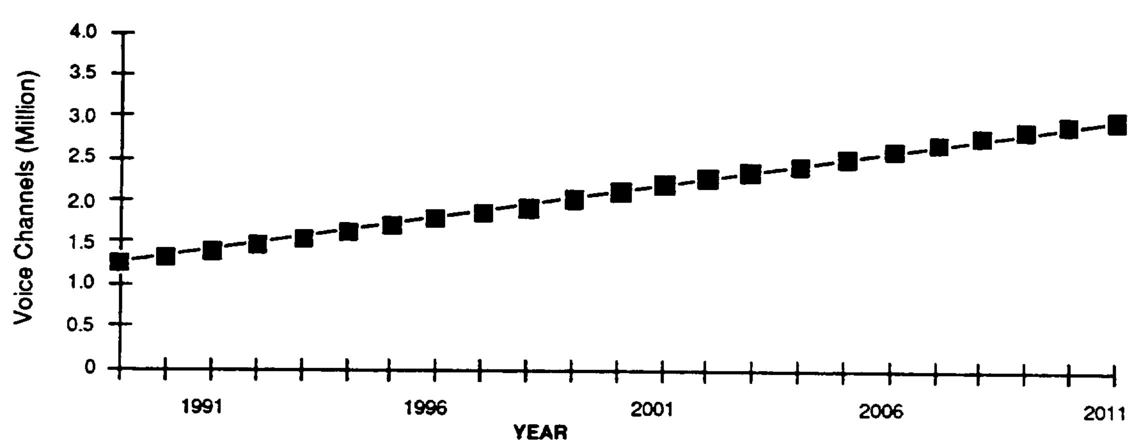
Private Line Service	Estimated Revenue ($Million)	Representative Cost/Line ($/Year)	Number of Private Lines	% Voice	Voice Channels Per Line	Number of Voice Channels
Analog voice-grade	1,400	3,848	360,000	100	1	360,000
FT1	260	15,392	17,000	50	6	51,000
T1	1,150	41,502	28,000	50	24	340,000
T3	200	331, 500	600	50	672	200,000

Source: Booz-Allen Analysis

The market for digital private lines showed remarkable growth in the late 1980's and early 1990's: (1980's: 17.3 percent, 1990's: 11.3 percent, CCMI/McGraw Hill 1991, vol. 1), (1980's: 36.2 percent, 1990's: 6.2 percent, Dataquest 1991). This growth has been balanced by a corresponding decrease in the market for analog lines: (1980's: -10.7 percent, 1990's: -6.9 percent, CCMI/McGraw Hill 1991, vol.1), (1980's: -3 percent, 1990's: -10.3 percent, Dataquest 1991). As the price for digital transmission continues to decrease, analog users will continue to make the switch to digital services. For example, Datapro projects the market for voice-grade analog service will decrease as users switch to FT1, T1, and eventually to T3 services (Data Pro Info. Services Group 1991). Irrespective of this movement from analog to digital, our methodology for determining the current number of voice channels per service is still valid. This total is a baseline number of channels that the market demands. This baseline value has a growth rate corresponding to the growth in number of users of private line services. Estimates of 15 percent per year from 1989 to 1991, 5 percent up to the year 2000, and 3 percent thereafter are used as a baseline projection for the growth of voice traffic on private lines. Figure 2-23 shows the baseline projection for voice traffic on private lines.

FIGURE 2-23
Baseline Private Line Projections

Year	Baseline Projection
1991	1,300,000
1996	1,650,000
2001	2,100,000
2006	2,400,000
2011	2,800,000



Source: Booz-Allen Analysis

2.3.3.3 Adjusted Projection. The baseline projections of private line voice traffic do not address factors that will affect market growth or decline during the study period. Two factors that may affect the growth of private lines are the continuation of price competition in the private line marketplace and the growing market potential for virtual networking services. These factors and percentage effects on the private lines baseline projections are discussed in the following paragraphs.

Price competition in the private line market is an important factor affecting the growth of private line voice channels throughout the study period. The cost-effectiveness of digital technology and fiber is one reason why users are already switching from their analog facilities to digital and it will continue to spur the growth of private line voice traffic. Specifically, the FT1 and DS0 services are very competitive with analog voice-grade and public switched services. A factor of 2 percent per year from 1991 through 1996 is used to increase the baseline growth of private line voice channels to account for continuing price competition.

As the IECs continue to improve the performance and reliability of their switched virtual networking services, high-volume users will tend to discontinue full-scale leasing of high-volume private lines (see Section 2.3.4, Private Networks.) This factor will decrease the growth of voice channels on private lines. A -7 percent factor per year in the 2000 to 2011 time frame is used to adjust the baseline projection to account for the effect of a growing software-defined network market.

The factors that have been discussed in this section are summarized in figure 2-24. These factors are used to adjust the baseline projection of private line voice channels. Figure 2-25 shows the adjusted growth of private line traffic and figure 2-26 shows the adjusted private line projections.

FIGURE 2-24
Summary of Private Line Factors

Factor	Effect on Baseline Projections	Duration Of Effect
Price Competition	+ 2%	1991 - 1996
Virtual Networks	- 7%	2000 - 2011

Source: Booz·Allen Analysis

2.3.4 Private Networks

The private network category includes all switched network services provided by the long-distance carriers as alternatives to the public telephone network and user-owned corporate network facilities. Private networking services include virtual networks, satellite networks, 56 kb/s switched, ISDN, and the new switched T1 service. Among the private networking services, virtual networks are the main carriers of voice traffic and will be the only private network service analyzed for the projections of voice channels.

Virtual networks are defined as software-defined network services offered to companies and institutions needing combined multisite services. The features that have traditionally been provided by using private lines have been increasingly replaced by the cost effectiveness and flexibility offered by virtual networks since their introduction in the mid-1980's (Zerbiec 1991, 25: 33-36). The features of virtual networks that will become significant in the late 1990's include

FIGURE 2-25
Adjusted Private Line Growth

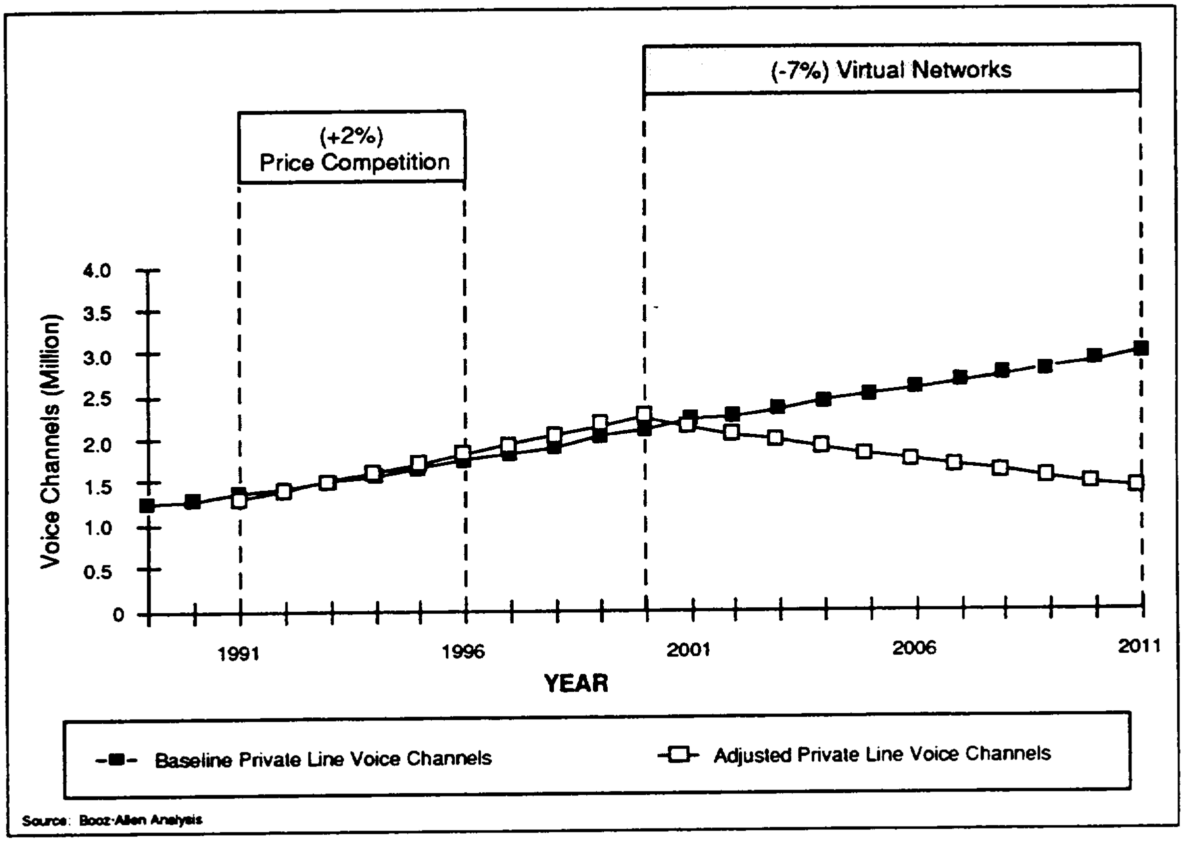


FIGURE 2-26
Adjusted Private Line Projections (Voice Channels)

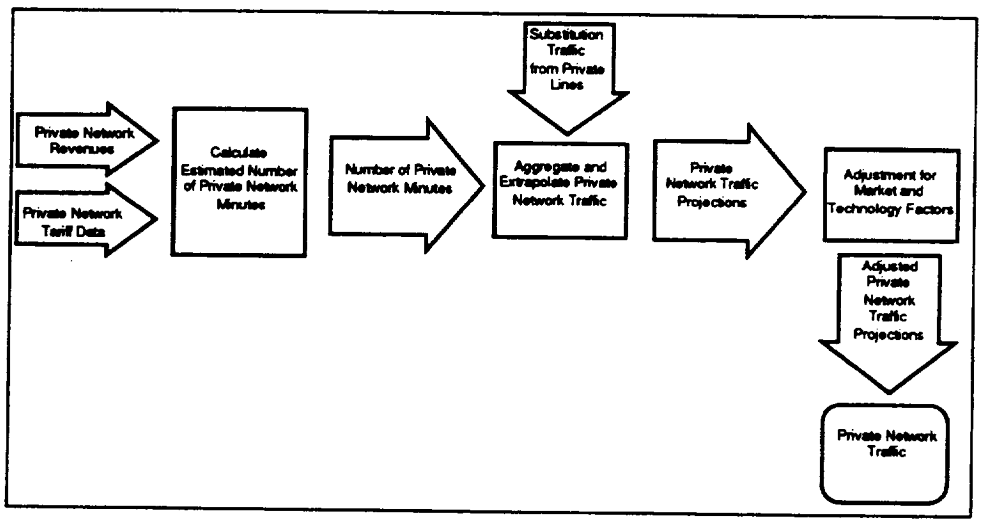
Year	Baseline Projection	Adjusted Projection
1991	1,300,000	1,300,000
1996	1,650,000	1,800,000
2001	2,100,000	2,100,000
2006	2,400,000	1,700,000
2011	2,800,000	1,400,000

Source: Booz·Allen Analysis

fully integrated voice and data services, real-time user control, on-demand bandwidth, and global virtual services in cooperation with foreign carriers (Heath 1991, 25:25-30).

Figure 2-27 shows the procedure used to forecast private network traffic. The market for private network services shows significant growth in virtual (software-defined) networks. Figure 2-28 shows the revenues for 1988 through 1990 for virtual networks, 56 kb/s switched, ISDN, and other private network services (Dataquest 1991). Data traffic has been growing as a percentage of the total traffic being carried over virtual networks. As shown in figure 2-29, by 1993 data traffic is projected to be 50 percent of the total amount of traffic carried on virtual networks (Heath 1991, 25: 25-30).

FIGURE 2-27
Private Network Data Flow Diagram

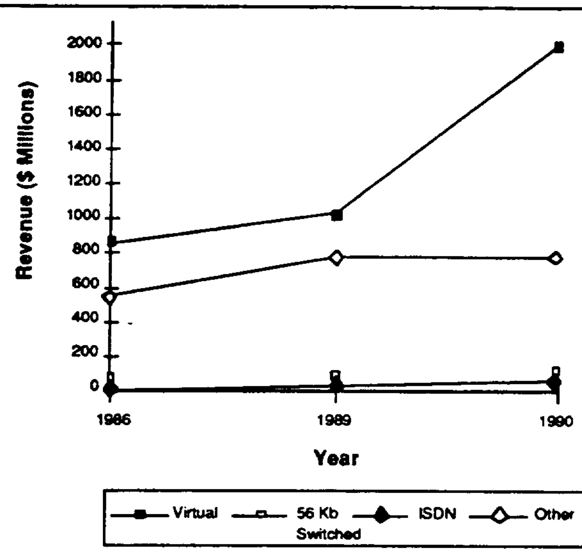


It has been predicted that virtual networks will provide the same level of telecommunications service currently found in the public switched voice networks. Services will include the following:

- Dedicated lines
- ISDN
- BISDN
- Shared data networks
- Wideband packet switching
- Network management services (Heath 1991, 25: 25-30).

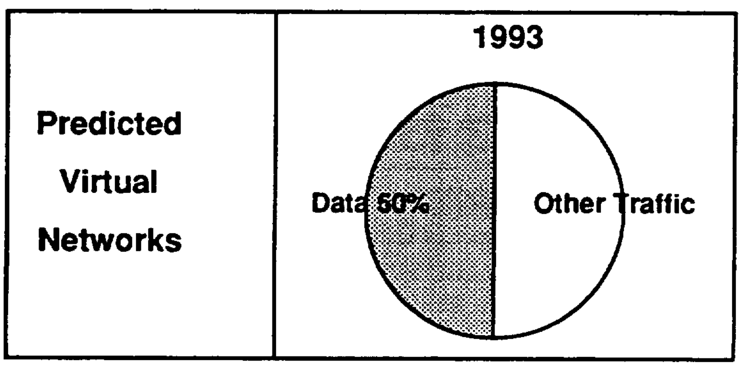
FIGURE 2-28
Private Network Revenues

Service	1988	1989	1990
Virtual	872	1085	2000
56 Kb Switched	27	45	66
ISDN	5	15	21
Other	573	679	690
Total	**1477**	**1824**	**2777**



Source: Dataquest 1991

FIGURE 2-29
Virtual Network Voice/Data Split



Source: Heath 1991

The growth of virtual network traffic will be as substitution for MTS traffic. This is because a business call is made when it is needed, independent of whether it is carried on a private network or on the Public Switched Network (PSN); frequently the person placing the call does not know which way it will be carried.

Our projections for MTS already include growth above today's level. Therefore, our baseline projection for virtual network traffic is to hold it constant at the 1991 level. Based on Figure 2-28, we estimate 1991 virtual network revenue to be $3 billion. At an average rate of 25¢ per minute, this gives traffic of 12 billion minutes per year.

In section 2.3.3.3, a 7 percent per year decrease in private lines was assumed from 2000 to 2011 as the effect of growth of virtual private networks. To determine the effect of this traffic on virtual networks, it was converted to switched minutes and included in the virtual network total to give our adjusted prediction for virtual networks. In the absence of any data on usage of private lines, the conversion was accomplished by dividing the cost per line of $3848 per year given in Figure 2-22 by 25¢ per minute to give the breakeven number of switched minutes per year for an average private line. This was then increased by 50 percent to account for usage above the breakeven point.

Figure 2-30 shows the baseline and adjusted projections for private network traffic.

FIGURE 2-30
Private Network Projections
(Millions of minutes per year)

Year	Baseline	Adjusted
1991	12,000	12,000
1996	12,000	12,000
2001	12,000	16,500
2006	12,000	33,000
2011	12,000	49,000

Source: Booz-Allen Analysis

2.3.5 800 Service

The 800 service or INWATS is inbound call service paid for by the called party. Typical uses of this service are market research, sales leads generation, customer service, accounts receivable, collections and shareholder or employee hotlines (Falkner Technical Reports Inc. 1991). There are two types of 800 services. The first type of services are those that use existing regular business lines. These services are aimed at smaller businesses and users. The second type of services are those that use dedicated access and/or private lines. These services are intended for high-volume users or users with pre-existing leased capacity. The market for 800 service is dominated by AT&T with about 78 percent of the market followed by MCI with about 15 percent of the market (Herman 1991). Other competitors include Sprint and intra-LATA offerings from the LECs.

2.3.5.1 Method. The flow chart in figure 2-31 shows the steps taken to project the number of voice channels used for 800 service. The 800 service voice channels are projected by extrapolating historical 800 service minutes and adjusting for market and technological trends. The historical data needed to make these projections are industry revenues and average cost per minute figures. These data are used to estimate the number of total yearly minutes used for 800 service. The next step in the process is using industry trends to extrapolate these minutes giving a baseline 800 service projection for 1991 to 2011. This baseline projection is then adjusted for market and technology factors to give an adjusted projection.

2.3.5.2 Baseline Projection. The estimated minutes per year for 800 service are based on industry revenues and average cost per minute. Dataquest estimates of 800 service revenues and costs per minute are shown in figure 2-32 (Dataquest 1991).

FIGURE 2-31
800 Service Data Flow Diagram

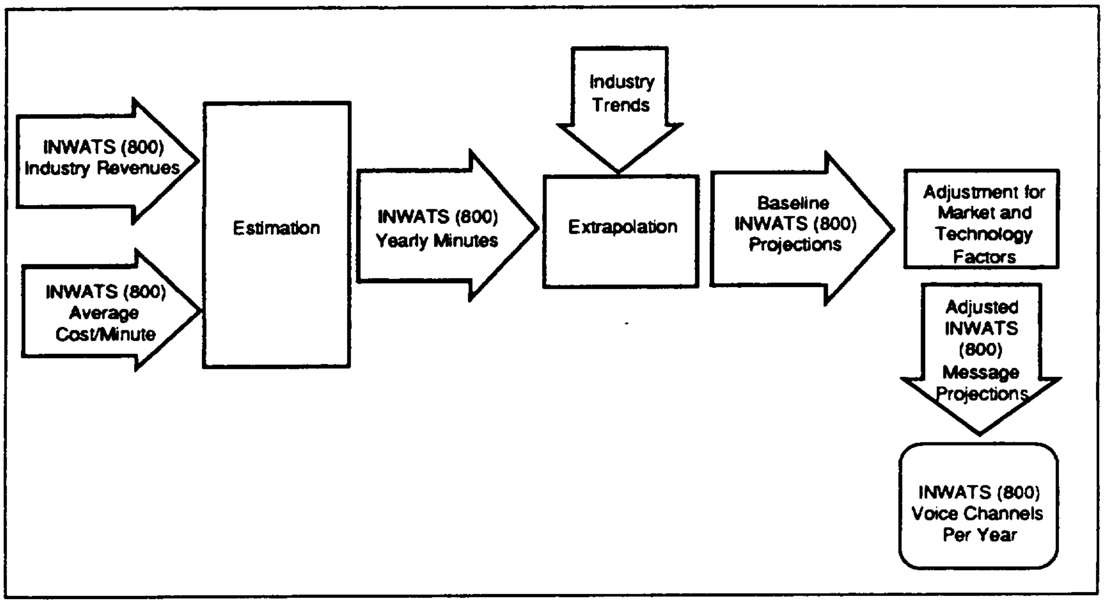
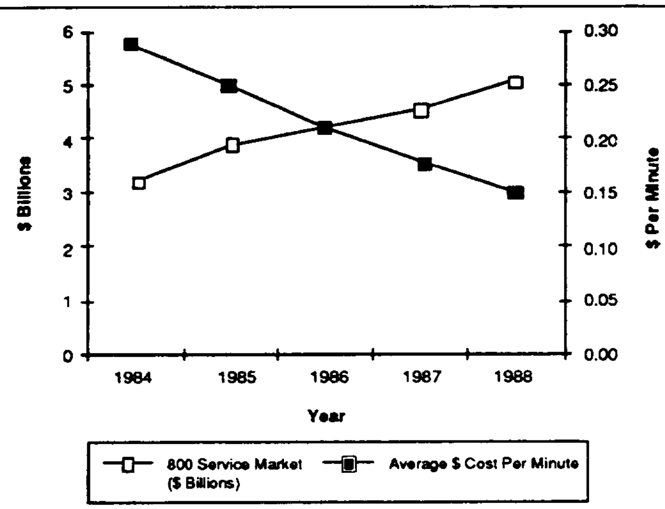


FIGURE 2-32
800 Service Revenues and Average Cost/Minute

Year	800 Service Market ($Billions)	Average $Cost Per Minute	Total Minutes (Billion)
1984	3.2	0.29	11.0
1985	2.9	0.25	15.6
1986	4.2	0.21	20.0
1987	4.6	0.18	25.6
1988	5.1	0.15	34.0

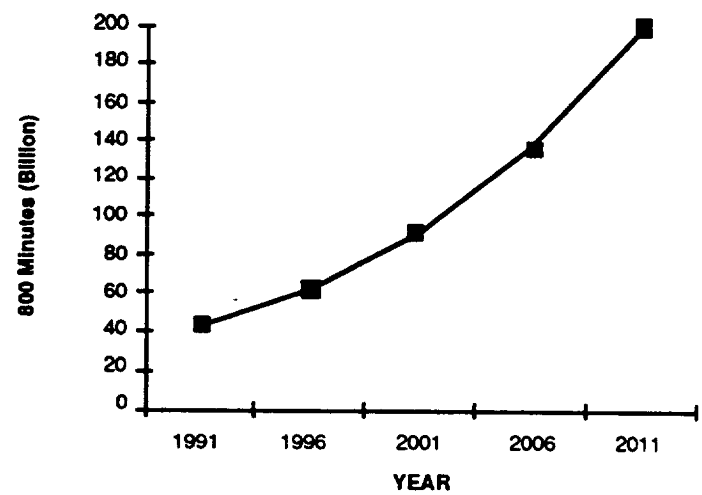


Source: Dataquest 1991

A growth rate of 8 percent is used for our baseline extrapolation. This estimate is based upon a projected decline in the 12.4 percent growth of the late 1980's and industry projections (Dataquest 1991). This baseline projection is shown in figure 2-33.

FIGURE 2-33
800 Service Baseline Projections

Year	Projected 800 Service Minutes (Billion)
1991	43
1996	63
2001	93
2006	135
2011	200



Source: Booz-Allen Analysis

2.3.5.3 Adjusted Projection. The growth of 800 service minutes over the target years of the study is affected by market and technology factors. These factors are used to adjust the baseline projections by percentage increases and decreases. The following are the factors used in this analysis of the 800 market are:

- New technology (Signaling System 7 [SS7], 800 data base)
- New services (30-minute recovery, small business 800, personal 800)
- Economic downturn
- Market saturation.

These factors are discussed in the following paragraphs.

The growth in the 800 marketplace shown in figures 2-32 and 2-33 is partly due to the introduction of new technology and software that allow nationwide access to 800 numbers. These innovations include SS7 and the national 800 number databases (Briere 1989, 6:51-53).

The introduction of new services by competing 800 service providers is another factor that affects the growth of 800 service minutes. The 800 service marketplace is increasingly becoming a commodity market as AT&T basic services are now virtually indistinguishable from those of MCI and Sprint (Falkner Technical Reports Inc. 1991). The introduction of new services is one way that 800 service providers try to distinguish their product from their competitors'. Some of the services that have been introduced include small business 800, personal 800 service, and 30-minute recovery guarantees (Herman 1991). The introduction of these services provides new opportunities for users that do not use 800 services, thus expanding size of the marketplace. To account the market effect of new services, a 2 percent factor is added to the baseline projection of 800 service minutes for 1991 to 1994.

The state of the U.S. economy has an observable impact on the way people do business. In difficult economic times, companies need to reduce budgets, including telecommunications budgets. One option for companies who offer customer support via toll free 800 service is to switch to caller-paid 900 services (Soft-Letter 1990, 7:1-2; Champenu). This trend is expected to have a negative 1 percent effect on 800 service minutes during economic recession, estimated for the years 1991 to 1993.

Market saturation in the 800 service market occurs when growth in the market drops to the level of overall telecommunications growth because most potential users of the service have been reached. The only growth remaining in the market will come from new users resulting from economic growth or new services. This factor is estimated at a negative 2 percent in 2000 to 2011.

The factors that have been discussed in this section are summarized in figure 2-34. These factors are used to adjust the baseline projection of private line voice channels. Figure 2-35 shows the adjusted projections.

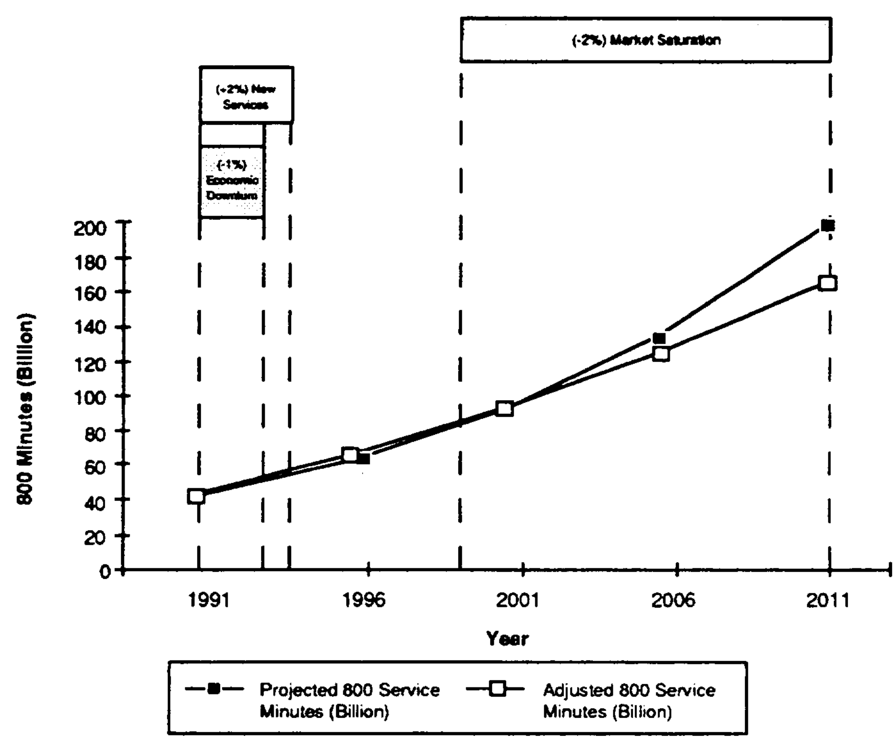
FIGURE 2-34
Summary of 800 Service Factors

Factor	Effect on Baseline Projections	Duration Of Effect
New technology (SS7, 800 data base)	Allows market to continue growth	
New services (30-minute recovery, small business 800, personal 800)	+ 2%	1991 - 1994
Economic downturn	- 1%	1991 - 1993
Market saturation	- 2%	2000 - 2011

Source: Booz-Allen Analysis

FIGURE 2-35
800 Service Adjusted Projections

Year	Adjusted 800 Service Minutes (Billion)
1991	43
1996	65
2001	94
2006	125
2011	170



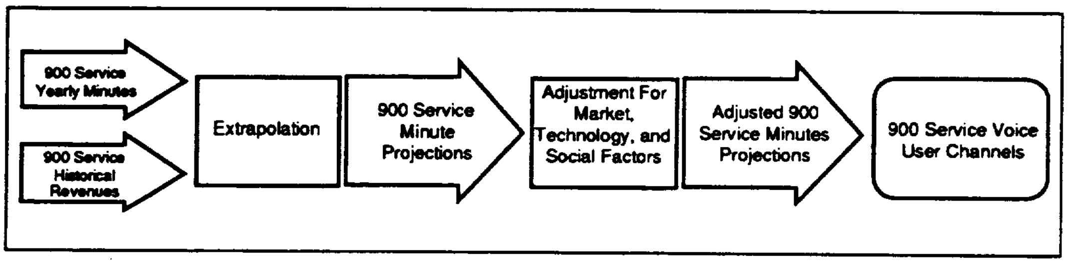
Source: Booz-Allen Analysis

2.3.6 900 Service

The 900 service is caller-paid inbound service. This service carries two-way conversations, prerecorded messages, and data communications for databases and computer-based ordering (Falkner Technical Reports Inc. 1991).

2.3.6.1 Method. Figure 2-36 summarizes the steps taken to project the growth of 900 service minutes. The 900 service yearly minutes and historical revenues are used to obtain a growth rate and projections for 1991 to 2011. These projections are then adjusted for market, technology, and social factors to obtain adjusted projections of 900 service minutes.

FIGURE 2-36
900 Service Data Flow Diagram



2.3.6.2 Baseline Projection. The 900 service market was dominated by information and entertainment applications in 1991, capturing 55.7 percent of the calls and 55.8 percent of the minutes. Figure 2-37 contains a snapshot of the 1991 900 service market (Callem 1991, 517-518). Historical revenues are shown in figure 2-38. Note that figures 2-32, 2-37 and 2-38 are from different sources and do not completely agree. The recent combined growth rate for 800 and 900 services has been 12 percent per year. In the absence of any trend data for 900 services alone, we used 12 percent per year simple growth (a total of 60 percent) for the period 1991-1996 and applied it to the 1991 data. We used the same incremental numbers of minutes and calls for each succeeding 5-year period. These baseline projections are shown in figure 2-39.

2.3.6.3 Adjusted Projection. The baseline projections of 900 service minutes do not address factors that will affect market growth or decline during the study period. Three factors that may affect the growth of the 900 service market are price competition, social effects, and economic downturn. These factors and percentage effects on the 900 service market baseline projections are discussed in the following paragraphs.

Price competition in the 900 service market may affect the growth of minutes in the study period. The price of 900 service varies considerably depending on the telephone company providing the service ((Soft-Letter 1990, 7:1-2) Price competition is estimated to cause a 3 percent per year increase in the 900 service market from 1992 to 1999.

FIGURE 2-37
1991 900 Service Market

Application	Percentage of Calls	Revenues ($ Millions)	Calls (Millions)	Minutes (Millions)
Information	35.6	347	98	278
Entertainment	20.1	196	55	157
Messaging	11.6	113	32	90
Ordering	7.1	69	19	55
Sweepstakes	5.9	58	16	46
Fund-Raising	5.4	53	15	42
Polling/Surveying	3.5	34	10	27
Lead Generation	2.9	28	8	23
Couponing	2.1	20	6	16
Dealer Locators	1.6	16	4	12
Customer Services	0.9	9	2	7
Other (including FAX)	3.3	32	9	26
Total	**100**	**975**	**274**	**779**

Source: Callem 1991

FIGURE 2-38
Historical Revenues for Combined 800 and 900 Services

Year	Revenues ($Billion)
1986	4.2
1987	4.6
1988	5.1
1989	5.7
1990	6.2

Source: Callem 1991

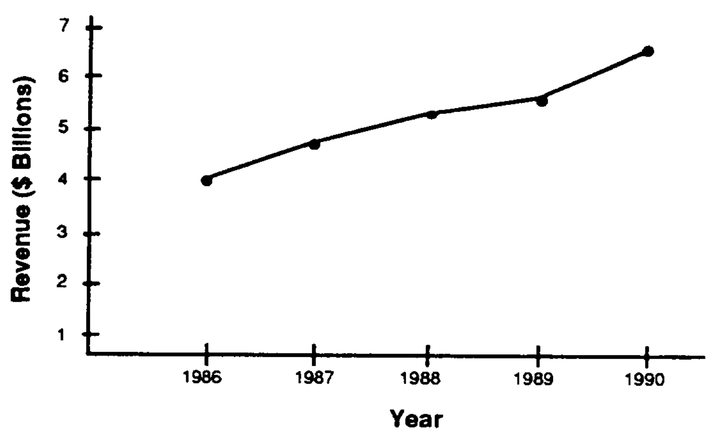
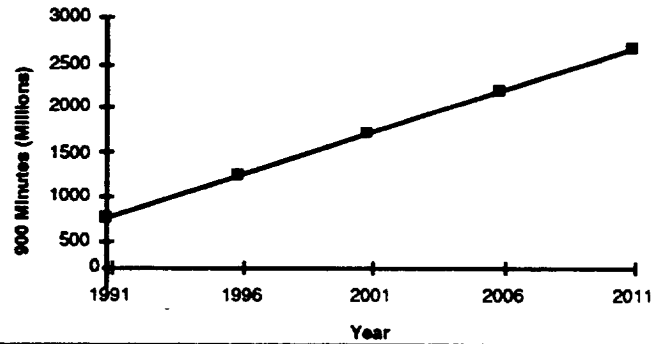


FIGURE 2-39
900 Service Baseline Projections

Year	Calls (Millions)	Minutes (Millions)
1991	274	779
1996	440	1250
2001	610	1700
2006	770	2200
2011	940	2700

Source: Booz-Allen Analysis



Social factors that affect the 900 service market include the customer's reluctance to pay for service that can be obtained free elsewhere and the social stigma associated with the 900 service market. The 900 service, now offered mostly by AT&T and MCI, has received much public attention because of the adult entertainment, chat line, and credit card services that have characterized the market. The FCC introduced rules in March 1991 regulating the provision of 900 services. The new rules include the following:

- Full price and content disclosure
- Customer rights to hang up without charge
- Free 900 call-blocking features
- No disconnection of local exchange service for nonpayment of 900 service charges (Taff 1991, 8:68)

A bill is pending in the U. S. Senate requiring the Federal Trade Commission and the FCC to establish rules on 900 programming services (Messner 1991, 8:11-12). Telesphere Communications, the only one of the four 900 service providers still handling adult services, filed for Chapter 11 bankruptcy in September 1991. Telesphere, with an estimated 27 percent of the market, was second only to AT&T in 900 service offerings (Blankenhorn 1991a). Sprint Telemedia announced in September 1991 that it would stop offering services to 90 percent of its current 900 service customers, thus eliminating all its romance, credit card, job, game, and horoscope lines (Blankenhorn 1991b). A negative 5 percent adjustment is used to account for the social effects on the 900 service market from 1991 to 1992.

As discussed in the section on 800 service, the state of the economy affects telecommunication services. One option for companies who offer customer support via toll-free 800 service is a switch to caller-paid 900 services (Soft-Letter 1990, 7:1-2; Champenu). This trend is expected to have a positive 1 percent effect on 900 service minutes during economic recession, estimated for the years 1991 to 1993.

The factors that have been discussed in this section are summarized in figure 2-40. These factors are used to adjust the baseline projection. Figure 2-41 shows the adjusted projections.

FIGURE 2-40
Summary of 900 Service Factors

Factor	Effect on Baseline Projections	Duration Of Effect
Price Competition	+ 3%	1992 - 1999
Social	- 5%	1991 - 1992
Economic Downturn	+ 1%	1990 - 1993

Source: Booz-Allen Analysis

FIGURE 2-41
900 Service Adjusted Projections

Year	Calls (Millions)	Minutes (Millions)
1991	274	779
1996	480	1350
2001	720	2000
2006	910	2600
2011	1100	3200

Source: Booz-Allen Analysis

2.3.7 Voice Summary

Summaries of the traffic projections for the voice categories are shown in Figure 2-42.

FIGURE 2-42
Voice Traffic Projection Summary

Year	MTS Call-seconds /Year (10^{12})	Private Lines Voice Channels (10^{6})	800 Minutes/Year (10^{9})	900 Minutes/Year (10^{9})	Private Network Minutes/Year (10^{9})
1991	23	1.30	43	0.78	12.0
1996	30	1.80	65	1.35	12.0
2001	40	2.1	94	2.0	16.5
2006	59	1.70	125	2.6	33
2011	87	1.40	170	3.2	49

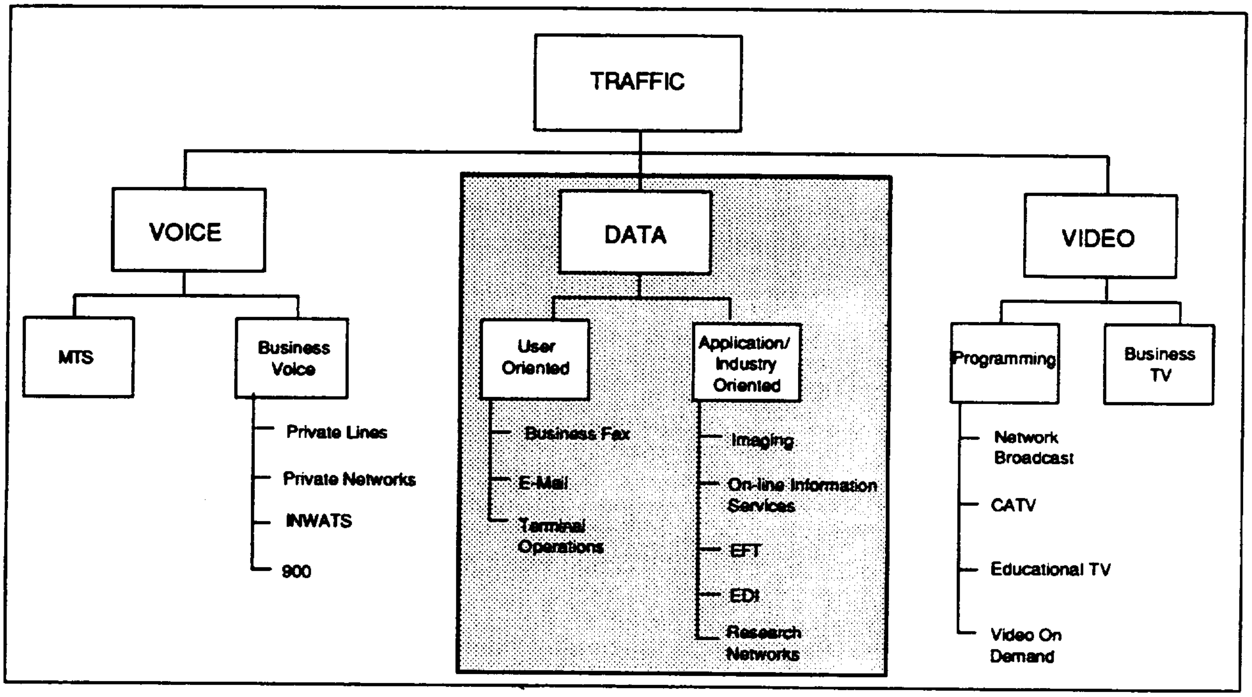
Source: Booz-Allen Analysis

2.4 DATA TRAFFIC

With the rapid advance of technology in the 1980's, the use of data communications has changed since the previous NASA studies of telecommunications demand. An example of these changes is the decline of telex as a significant contributor to long-distance data traffic. This decline can be attributed to the increased use of personal computer connectivity as well as facsimile (fax), electronic mail (e-mail), and other forms of business messaging. Additional evidence of these changes is shown in the voice section where data applications drive the growth of the private line market.

The data traffic section looks at the demand for telecommunication services over the study period 1991 to 2011. Several major data-generating applications are examined to determine the projected growth of data traffic. These applications are divided into two categories: user-oriented and application/industry-oriented data traffic. Figure 2-43 highlights the data category and shows the segments of demand that make up this category.

FIGURE 2-43
Data Traffic Categories



2.4.1 User-Oriented Data Traffic

The user-oriented data traffic category includes facsimile, electronic mail, and terminal operations. This category describes the growth of applications whose growth is driven by individual users.

2.4.2 Business Facsimile

Facsimile is the process by which written, printed, or graphic material is transmitted over phone lines to a remote terminal, producing a replica of the original document in seconds. Recent reductions in cost and improvements in speed have made the fax machine an essential part of the office environment. This section discusses the traffic projections made for business fax, whether the fax is sent from offices or from the home.

The International Telegraph and Telephone Consultative Committee (CCITT) has classified facsimile machines into four groups based on transmission speeds: groups 1, 2, 3, and 4. Group 1 is primarily an analog system with a transmission speed of 6 minutes per page, while group 2, also analog, has a transmission speed of 3 minutes per page. Primarily digital systems, groups 3 and 4 transmit in the range of 5 to 60 seconds per page. Figure 2-44 shows the different categories of fax machines, their transmission speeds, and current trends.

FIGURE 2-44
CCITT Categories of Fax Machines

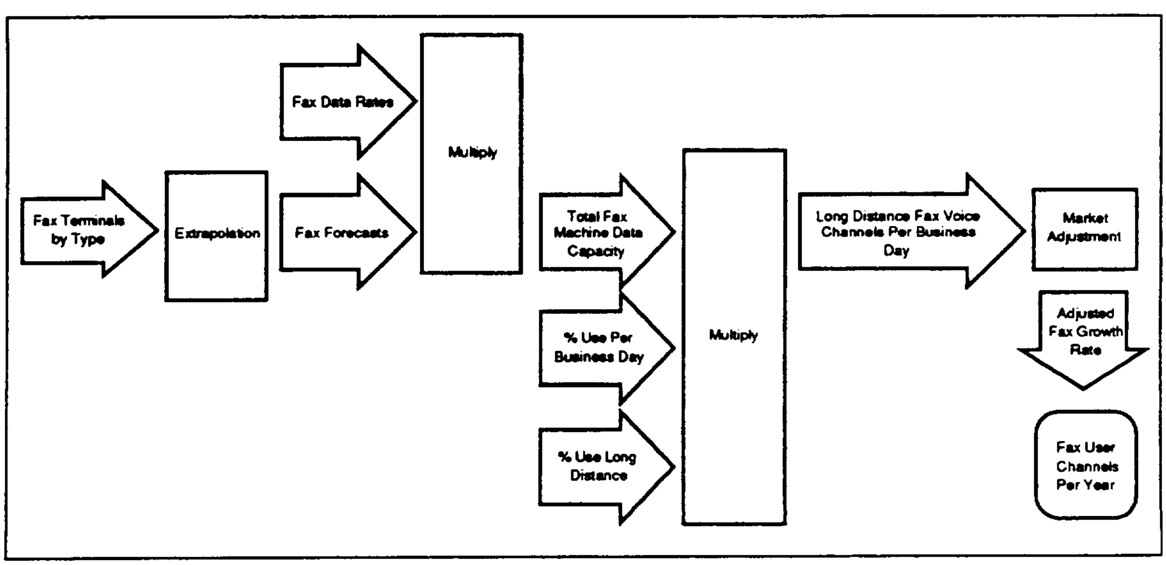
Group	Transmission	1-Page Document Speed	Trend
I	Analog Frequency Modulation	6 Minutes	Obsolete
I	Analog Amplitude Modulation	3 Minutes	Obsolete
III	Digital Encoding	1 Minute	Strong, Steady Growth
IV	High Speed Digital	5 Seconds	Strong Growth
V	High Speed Digital Color	3-12 Seconds	Proposed (Year 2000)

Source: CCITT, Kratochvil 1991

Group 5 facsimile is an emerging standard that provides a high-speed digital color fax capability. This capability is proposed for the turn of the century but opinions differ on the relative importance of this group, since color fax implementations based on group 3 and 4 standards are already emerging (Kratochvil 1991).

2.4.2.1 Method. Facsimile traffic estimation (for group 3 and group 4 machines) is based on current and future technologies (See figure 2-45.) The number of installed fax machines is extrapolated over the period of the study using s-curves and industry trends. The projected fax machine population is then used to estimate the total amount of long-distance fax traffic generated. This baseline projection of fax traffic is then adjusted by market and technology factors that could affect fax growth.

FIGURE 2-45
Facsimile Data Flow Diagram



2.4.2.2 Baseline Projection. Since its introduction, the fax machine has evolved from a technological novelty to becoming an important part of everyday business and therefore an integral part of the telecommunications market. The following are reasons for the increased acceptance and use of the fax machine:

- Increase in speed (a document can now be transmitted in less than 60 seconds with clear resolution)
- Ease of installation (requires minimal setup)
- Flexibility of use (can transmit text or graphics 24 hours a day, 7 days a week)
- Ease of use
- Automated operation (requires very little human interaction).

Only the growth of group 3 and 4 facsimile terminals is assessed in this section of the study because current market trends show that group 1 and group 2 will become obsolete by 1995 (Lee Weinstein, telephone interview, January 1992). The *Information Technology Industry Databook* is used as the primary source of historical data for group 3 and 4 fax machines (CBEMA 1988, 142). Figure 2-46 shows the installed base of fax machines for 1983 to 1989. Figure 2-47 shows the exponential growth curves for group 3 and group 4 machines.

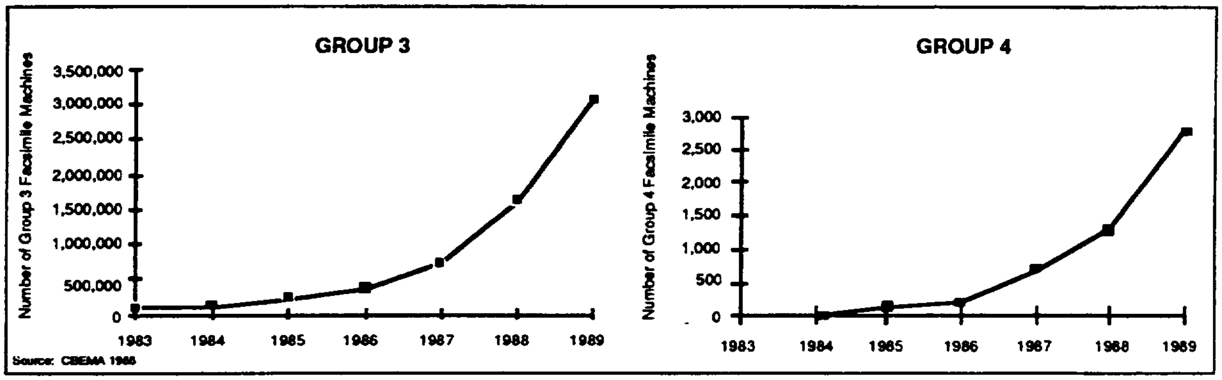
FIGURE 2-46
Installed Base of Fax Machines

Year	Group 3	Group 4	Total
1983	75,200	0	75,200
1984	124,200	0	124,200
1985	250,900	100	251,000
1986	400,200	200	400,400
1987	752,100	700	752,800
1988	1,641,200	1,300	1,642,500
1989	3,076,000 *	2,800	3,078,800

*Other industry estimates indicate approximately 3.6 million group 3 fax machines

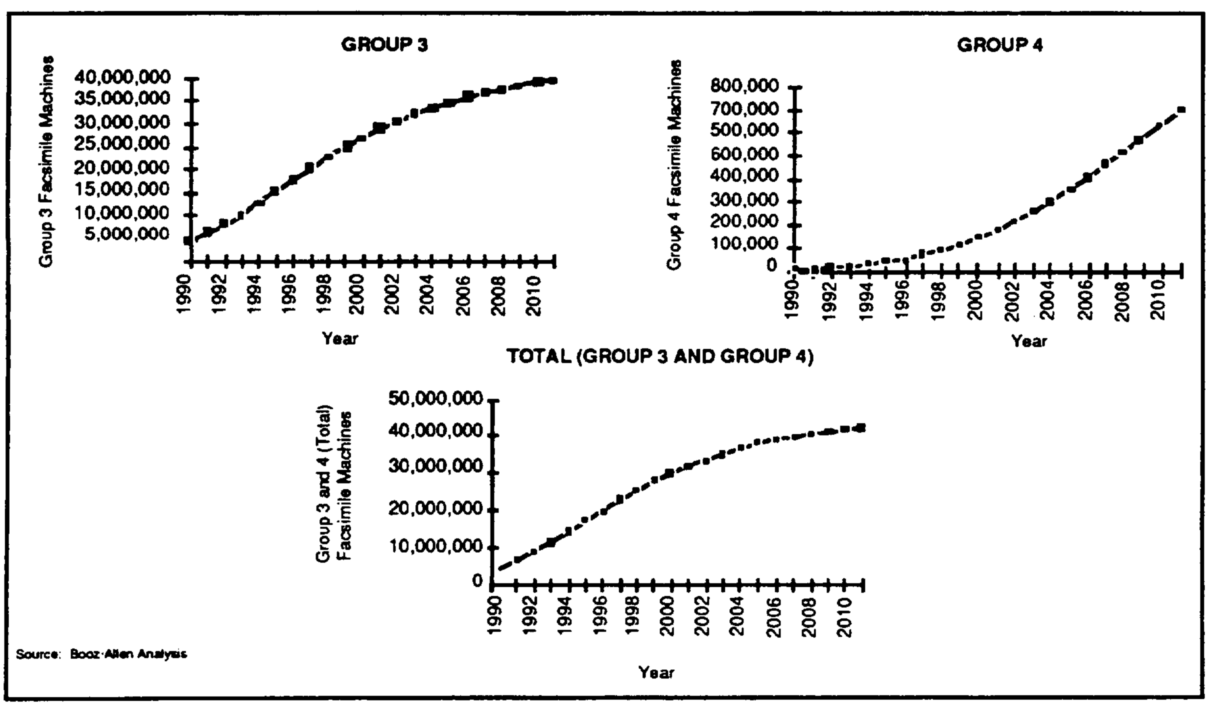
Source: CBEMA 1988

FIGURE 2-47
Growth Curves for Group 3 and Group 4 Fax Machines



The current growth of the fax market is typical of technology-driven markets that have a slow start, then steep growth, and then a plateau (Wheelwright 1980, 271). Group 3 fax is currently exhibiting strong growth that will decline over time as market saturation takes effect. This technology-driven growth is characterized by the s-curve. Since substantial growth is estimated to continue in the fax market through the turn of the century, the year 2000 is used as the point in which the s-curve for group 3 flattens. Group 4 fax is still in its initial stage of slow growth and therefore is not expected to reach saturation in the time frame of this study. Figure 2-48 illustrates the extrapolation of groups 3 and 4 data for the years 1991 through 2011.

FIGURE 2-48
Baseline Projection of Group 3 and Group 4 Fax Machines



There are two possible scenarios for the growth of groups 3 and 4 fax machines. In the standards-driven scenario, as full high-speed digital connectivity for fax machines prevails and group 4 prices come down, group 4 fax machines will start to replace group 3 fax machines. The other possible scenario for fax is one where the group 3 machines improve and take on the characteristics of group 4 machines, eliminating the need for a new type of machine (Kratochvil 1991). The result of either scenario is that a market exists for a facsimile capability. Our study measures this demand by examining the current and projected market for the total number of group 3 and group 4 machines. The combined fax projection is also shown in figure 2-48.

Using the number of forecasted facsimile machines, the next step in forecasting fax traffic is determining the estimated fraction of the time that fax machines are used per business day and the fraction that represents long-distance faxes. Through market research and discussions with functional experts from major facsimile vendors, a 15 percent estimate of business day fax usage was identified and a 50 percent long-distance utilization were obtained (Ted Morgan, telephone interview, January 1992). For example, one source reports that 67 percent of all faxes transmitted by Fortune 500 firms are sent long distance (Network World 1992). A 50 percent estimate is used to take into account the smaller amount of long-distance faxes sent by smaller firms. This estimate may be too high as the percentage of long-distance fax messages may decrease over the course of the study. This ratio could decrease as the number of fax machines being used for local business increases and fax traffic becomes more like normal telephone calling patterns (Kratochvil 1991).

Two factors determine our assumptions about fax transmission time per day: the number of pages transmitted from each fax terminal daily, and the proportion of faxes sent at 64 kb/s. Both of these factors will change during the forecast horizon. Using the estimate given above of 15 percent business day fax usage for an 8-hour day gives 72 minutes per day. Because half the time is transmission and half reception, fax usage was about 35 minutes per day in 1991. At 60 seconds per page, this translates to 35 pages transmitted per day. We project that this number of pages will decrease to 5 per day in 2001 and remain at that level as e-mail accounts for an increasing portion of text transmissions and fax machines proliferate in offices. The proportion of 64 kb/s faxes will increase with the adoption of ISDN. In 1991, the average PSN fax transmission rate was 4.8 kb/s, transmitting one page in 60 seconds. By 2006, all fax transmission will be sent at 64 kb/s, transmitting a page in 5 seconds.

The relationship between ISDN and transmission time is as follows. Groups 3 and 4 fax terminals have adjustable-speed modems that determine the highest bit rate sustainable for each connection. Currently, the highest sustainable bit rate averages about 5 kb/s over a voice-grade line. The long-distance portion of the call uses one 64 kb/s DS0 to transmit 5 kb/s. When ISDN is available, a modem will not be needed and the fax machine will be able to transmit at a full 64 kb/s. One page will then require about 5 seconds, including call setup time.

Figure 2-49 details our assumptions about the timing of changes to fax usage per day and figure 2-50 shows the total fax minutes per year.

FIGURE 2-49
Business Fax Usage Per Day Assumptions

		Fax Percentage at: 60 Sec.	5 Sec.	
Year	Pages/Day	(POTS)	(ISDN)	Sec./Term./Day
1991	35	100	0	2100
1996	25	80	20	1250
2001	5	50	50	165
2006	5	0	100	25
2011	5	0	100	25

Source: Booz·Allen Analysis

FIGURE 2-50
Fax Usage Estimates

Group 3

Year	Group 3 Machines (Millions)	Time Used per Business Day (sec.)	% Use Long Distance	Group 3 Fax Minutes Per Year (Billion)
1991	6.3	2100	50	28
1996	18.C	1250	50	47
2001	29	165	50	10.0
2006	36	25	50	1.90
2011	40	25	50	2.1

Group 4

Year	Group 4 Machines (Thousands)	Time Used per Business Day (sec.)	% Use Long Distance	Group 4 Fax Minutes Per Year (Million)
1991	7.8	2100	50	34
1996	52	1250	50	135
2001	18C	165	50	62
2006	41C	25	50	21
2011	70C	25	50	36

Source: Booz·Allen Analysis

2.4.2.3 Adjusted Projection. There are several factors that may increase the growth of the fax market even more than indicated in our baseline projections. These factors, obtained through discussions with facsimile industry experts and research of related literature, include the following:

- Price competition
- Market saturation (International Resource Development Inc. 1989)
- Personal Computer (PC) fax boards and networked PC fax servers (Datapro Research Group 1990, MT60-500-101-n1.)
- Home consumer market
- ISDN compatibility (Datapro Research Group 1990, MT60-500-101-n1).

These trends that will influence the growth of the fax industry over the next several years are addressed below.

"In 1985 the lowest list price for one 9600 b/s group 3 facsimile terminal was 28.6 percent below the equivalent 1984 price, continuing the exponential price decline since 1980 which ran as high as 33 percent a year." (*Office Products Analyst,* May 1986). This statement shows that competition has been and will continue to be a driving force in the price wars between the various facsimile vendors. Considering residual economies of scale, learning curves, and lower electronics costs, the effect of price competition is assumed to be a 2 percent compounded growth rate increase through 1996.

The Office Products Analyst stated in 1986 that "the Fortune 1000 continues as a good market for facsimiles, particularly upgrades, but the real growth is among many smaller companies which are now getting their first facsimile machines." The reliability of Group 3 machines has increased dramatically and the problems associated with telephone systems have dissipated. The facsimile is a widely accepted commodity, and the major vendors compete on reputation, price, and service presence. Because the market is quickly becoming heavily saturated, facsimile growth will slightly decrease (International Resource Development Inc. 1989). The forecasted decrease is -1 percent projected over the period 1994 to 2011.

Personal computers can easily be converted to Group 3 facsimile devices by inserting an expansion board and connecting a telephone line to the PC. By doing this, the user can transmit and manipulate facsimiles created from a computer screen, and receive facsimile messages over the terminal or print to an attached printer device. The popularity of this technology will continue to grow (Datapro Research Group August 1990, MT 60-500-101-n1). Additionally, fax servers are another means of sending fax messages from the PC. These devices are attached to PC Local Area Networks (LAN) and send messages from clients on the network. The relatively low cost and ease of use of PC-generated facsimile is expected to increase the fax growth rate by 1 percent over the next 20 years.

One recent improvement in fax machines has made them more attractive for home and small business use. Many fax machines have added the capability of sharing a regular voice line, freeing home users and small businesses from having to obtain an extra data-only line for the fax. This feature allows the machine to answer the telephone, switch to fax mode if needed, receive fax messages, and print the incoming document. In October 1990, Sharp introduced a user-friendly facsimile and telephone answering device to the Japanese market (*Office Products Analyst* March 1991). Since that time, Sharp has had to adjust its production schedules to place 70,000 additional machines in Japan. Because of the successful penetration of the foreign market, this device is expected to create the same type of sales in the U.S. market in the next several years. CAP International expects significant penetration of small businesses as a critical mass of ownership is achieved. Facsimile penetration is projected to increase to over 80 percent of small businesses in the mid-nineties. This is expected to expand the facsimile market by 2 percent over the next 20 years.

Given the tremendous potential size of the home fax market, the impact of facsimile demand on the telephone network has to be considered. One solution is to promote the penetration of ISDN into the residential market (Datapro Info. Services Group March 1991). ISDN allows each access line to carry both voice and facsimile simultaneously. Because there are many different kinds of machines, existing compatibility is a distinct advantage. The greater number of individual terminals that can communicate with each other, the greater the utility and economies of scope. The next step is to incorporate ISDN capability into the facsimile device, which is currently being considered. A growth rate of 2 percent is used in the final projection.

The five factors discussed as adjustments to the baseline projections of fax traffic are summarized in figure 2-51. Considering the five factors that have been discussed and their corresponding impact on the facsimile growth rate, the baseline projections for fax growth are adjusted and shown in figure 2-52. Additional factors that may affect fax growth are the following:

FIGURE 2-51
Summary of Fax Factors

Factor	Effect on the Growth of Fax Minutes	Duration of Effect
Price Competition	+ 2%	1991 - 1996
Market Saturation	- 1%	1994 - 2011
Fax Boards on PCs	+ 1%	1991 - 2011
Home Consumer Market	+ 2%	1991 - 2011
ISDN Compatibility	+ 2%	1996 - 2011

Source: Booz-Allen Analysis

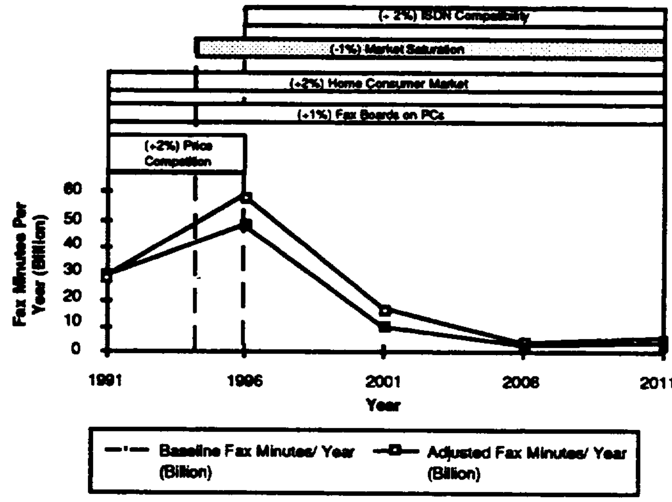
- Thermal printing capabilities
- Export sales of couplers and modems increasing
- New interface standards (i.e., the shift from RS232 to RS449)
- Faster facsimile group 4 machines
- PC and LAN technology teaming up with voice and e-mail
- Mobile facsimiles using cellular devices and systems
- Fax-on-demand services available through voice processing systems.

The traffic estimates given above considered only business use of facsimile. A similar analysis can be carried out for residential facsimile usage. Because the resulting numbers are very much smaller and are highly speculative, an abbreviated analysis will be given here to illustrate the small contribution that residential use makes to busy-hour facsimile traffic.

Since there is essentially zero usage of residential facsimile now, it is assumed that the maximum use will be at the end of the study period, in 2011. That is, while the diversion of some business facsimile traffic by e-mail will also occur for residential use, nonetheless residential facsimile traffic will continue to increase over the whole study period. Based on the number of households in the country and a high penetration rate, we estimate 100 million residential fax machines in 2011. We assume that each machine sends two pages per day and 10 percent of this traffic represents long-distance calls. ISDN penetration of residences is assumed to be 80 percent by 2011, so 80 percent of the pages will be transmitted in 5 seconds and 20 percent in 60 seconds. This gives 320 million seconds per day of long-distance transmission from residential fax machines. Converting this to the business busy hour by dividing by 24 to give average hourly usage and multiplying by a peaking factor of 0.4 (see section 2.6) gives 5.3 million call seconds. Because there are 3600 seconds in the busy hours, the result is residential fax traffic of about 1500 DS0s during the business busy hour. This is less than 10 percent of the business use, which in turn is a small fraction of the voice use. Therefore, we conclude that residential facsimile usage will at best have a negligible impact on our projections.

FIGURE 2-52
FAX Adjusted Projections

Year	Baseline Fax Minutes/ Year (Billion)	Adjusted Fax Minutes/ Year (Billion)
1991	28	28
1996	47	58
2001	10.0	16.0
2006	1.90	4.0
2011	2.1	5.4



Source: Booz-Allen Analysis

2.4.3 Electronic Mail

E-mail is a computer-based application that sends electronic messages between user mailboxes over a telecommunications network. The messages have traditionally been text but new standards provide for the transmission of binary files, images, and fax.

The e-mail user population includes users of public systems, private systems, and research networks. Representative examples of these users are shown in figure 2-53.

FIGURE 2-53
The e-mail User Population

Public System	AT&T Mail, Easylink Sprintmail Dialcom, BT-Tymnet Compuserve Infoplex, Easyplex MCI Mail GE Info Services (Quick-Comm, GEnie)
Private Systems	Centralized (UNIX, IBM, DEC) LAN-Based (Lotus cc:Mail, Microsoft Mail, CE Software Quickmail)
Research Networks	Internet

There are several key issues that are shaping the electronic messaging industry. These trends include the following (International Resource Development Inc. 1989):

- Regional Bell Operating Company (RBOC) participation
- Standardization and connectivity

- Non-interpersonal electronic messaging (intra-enterprise, EDI, noninteractive transactions, intercompany messaging)

- Electronic messaging alternatives (growth of fax, voice mail, growth of LAN-based alternatives)

- LAN vs mainframe e-mail

- Migration from public to LAN-based e-mail.

These issues are also reflected in statistics from a study done by the Electronic Mail Association (EMA) on North American companies with at least $500 million in annual revenue that indicates:

- The firms currently using e-mail expect to add an average of 23 percent more users each year.

- 25,000 new sites are considering implementing e-mail within the next 2 years.

- 42 percent of headquarters sites use e-mail; 33 percent of branch sites use e-mail.

- 45 percent of employees at headquarters sites use e-mail; 26 percent of employees at branch sites use e-mail.

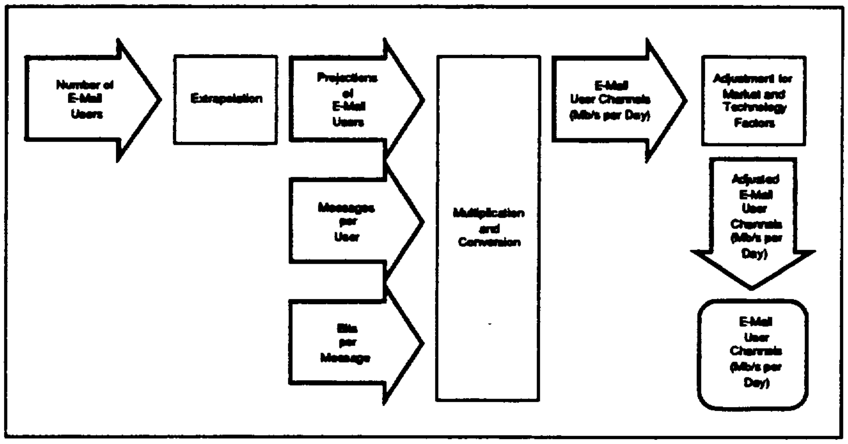
- These ratios will change as headquarters sites predict a 38 percent increase in e-mail usage next year and branch offices predict an 80 percent increase.

- Almost half of all headquarters-originated traffic is bound for another location; more than 80 percent of the messages originating at branch locations are destined for headquarters, other branches, or another firm.

- About 5 percent of headquarters and 3 percent of branch traffic are sent to another company; this fraction is likely to increase quickly as X.400 and X.500 are widely deployed (Datapro Research Group August 1990, MT60-500-101-n1).

2.4.3.1 Method. E-mail traffic projections are based on the growth of the e-mail user population described in figure 2-53. This projection of e-mail users is then multiplied by the estimated number of messages per user and the size of each message to determine the total amount of projected e-mail data traffic. The effects of external market and technology factors that affect the growth of e-mail traffic are taken into account by varying the estimates of number of messages per user and message size over the course of the study. The data flow diagram for the projection of e-mail traffic is shown in figure 2-54.

FIGURE 2-54
E-Mail Data Flow Diagram



2.4.3.2 Baseline Projection. Figure 2-55 lists the data describing the e-mail user population from 1980 to 1990 for public users, private centralized users, and private LAN users (International Resource Development Inc. 1989; The Yankee Group 1988; Communications Week 4 November 1991; Communication News August 1990). This figure also contains industry projections for the years 1991, 1994, and 1999. Figure 2-56 shows the graph of this growth in the e-mail user population, dominated by projected LAN user growth between 1990 and 1994.

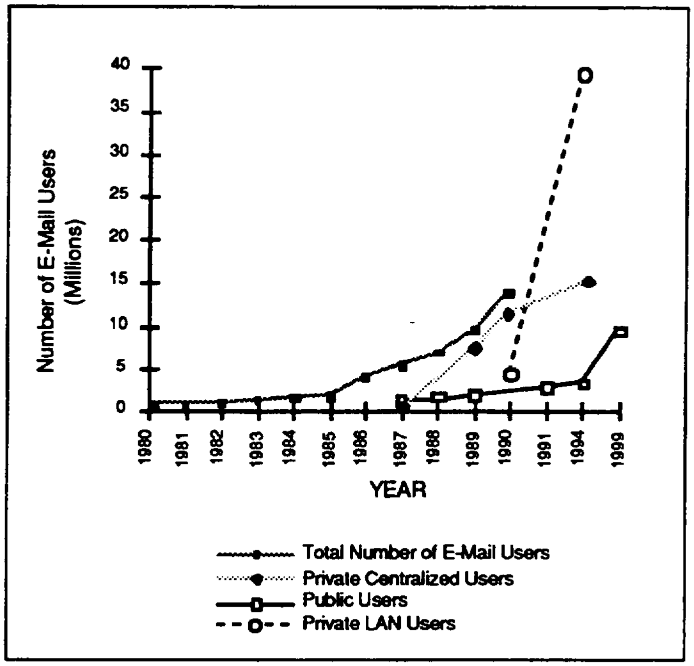
FIGURE 2-55
The E-Mail User Population

Year	Total Number of E-Mail Users	Public Users	Private Centralized Users	Private LAN Users
1980	430,000			
1981	470,000			
1982	540,000			
1983	670,000			
1984	1,000,000			
1985	1,670,000			
1986	4,100,000			
1987	5,250,000	1,000,000	*2,105,000	
1988	6,960,000	1,485,000		
1989	8,600,000	1,835,000	6,755,000	
1990	12,430,000		10,000,000	3,700,000
1991		*2,400,000*		
1994		*4,000,000*	*14,600,000*	*36,200,000*
1999		*9,000,000*		

Note: *Numbers in italics are projections*
* Incomplete Data

Sources: International Resource Development Inc. 1989
The Yankee Group 1988
Communications Week 4 November 1991
Communications News August 1990

FIGURE 2-56
Growth of E-Mail Users



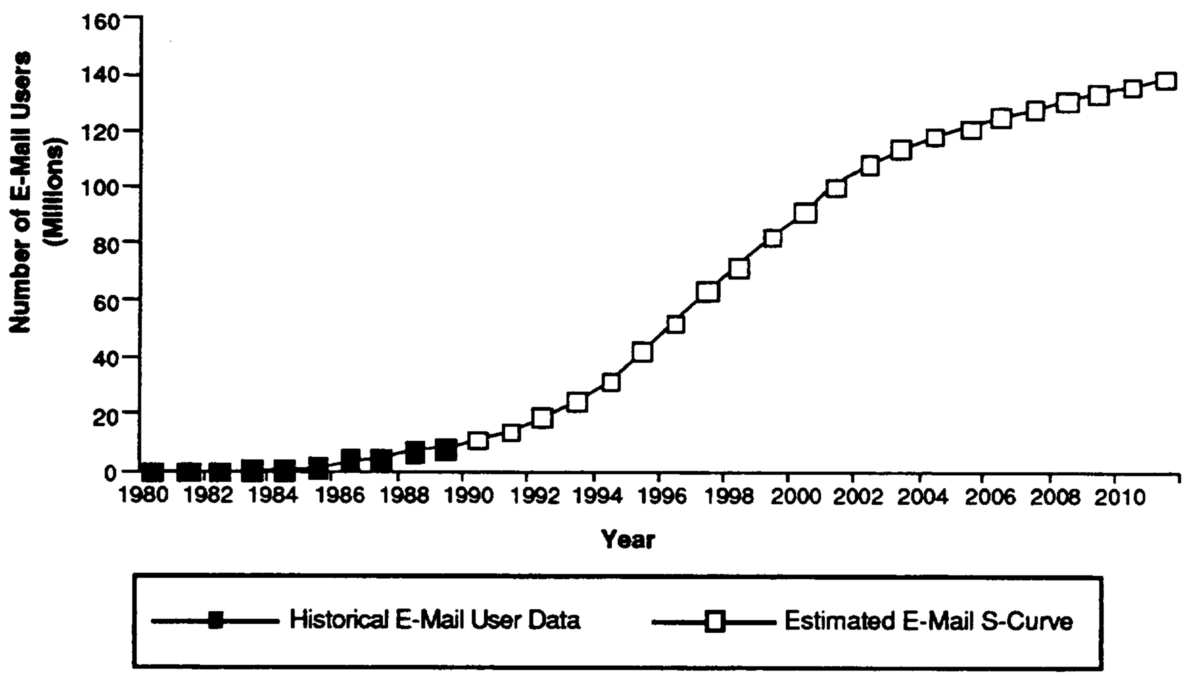
Sources: International Resource Development Inc. 1989
The Yankee Group 1988
Communications Week 4 November 1991
Communications News August 1990

The e-mail user population has historically been composed of centralized users, but LAN-based users show the most significant current market growth as e-mail achieves "critical mass." Similar to the growth of the PC software market, e-mail growth is triggered by the market phenomenon known as "critical mass" (Information Hotline April 1986). Critical mass is the point at which e-mail users can reach most of their contacts electronically (McCusker 1991). Before a critical mass of users were using e-mail, the market growth was relatively slow. With factors including acceptance by business users, decreasing cost of usage, and network interconnections increasing the number of users, e-mail growth has exploded.

The exponential growth of the total e-mail user population demands the use of s-curve methodology to project the growth of e-mail traffic through 2011. Figure 2-57 shows the result of this projection. The growth of the baseline curve between 1980 and 1990 is dominated by centralized environment e-mail users (Communications Week 4 November 1991). The exponential growth starting in 1990 is tied predominantly to the growth of LAN-based e-mail users (Telecommunications August 1991). The value of 140 million e-mail users in 2011 is based on the data in figure 2-64. This figure projects 29 million terminals and 110 million PCs in use in 2011. It is assumed that all of them are capable of originating e-mail, either directly to the PSN or a private network or through an e-mail gateway attached to a LAN. While this is possible an overestimate, it is partially compensated for by not considering e-mail that may arise in other ways, for instance from computers, fax machines, or voice-mail systems.

FIGURE 2-57
Growth of the Total E-Mail Population

Year	E-Mail Users (millions)	Year	E-Mail Users (millions)
1980	0.43	1996	*53*
1981	0.47	1997	*64*
1982	0.54	1998	*74*
1983	0.67	1999	*84*
1984	1.00	2000	*93*
1985	1.67	2001	*100*
1986	4.10	2002	*110*
1987	5.25	2003	*115*
1988	6.96	2004	*120*
1989	8.60	2005	*125*
1990	*12.4*	2006	*125*
1991	*15*	2007	*130*
1992	*20*	2008	*130*
1993	*26*	2009	*135*
1994	*33*	2010	*135*
1995	*43*	2011	*140*



Source: Booz·Allen Analysis

FIGURE 2-58
Long-Distance E-Mail Data Traffic Projections

Year	Number of E-Mail Users (Millions)	Messages/ User/Day	Messages/Day (Millions)	Megabits/ Message	E-Mail Terabits/Day	% Messages Carried By LD	LD E-Mail Terabits/Day
1991	15	1	15	0.03	0.45	1	0.0045
1996	53	3	160	0.10	16.0	10	1.60
2001	100	7	700	0.50	350	25	88
2006	125	10	1250	1.00	1250	35	440
2011	140	11	1500	1.50	2300	40	920

Source: Booz·Allen Analysis

Long-distance e-mail data traffic per day is estimated based on the projected e-mail users, average messages per day, and average bits per message. These projections are shown in figure 2-58. The average messages per user estimates are made based upon estimates of public e-mail messages (International Resource Development Inc. 1989) and the EMA predictions for corporate messages in 1995 (Network World 4 November 1991, 6). The number of messages per year is increased based on projections of critical mass in electronic mail communication. The average megabits per message and long-distance message percentages are Booz·Allen estimates based on published industry surveys of corporate e-mail users (Telecommunications November 1991; Cope 1991, 32).

2.4.3.3 Adjusted Projection. The growth of e-mail data traffic over the target years of the study is affected by several factors, some of which have already been discussed. The most significant factors (interconnectivity, directory availability, integrated application development, and integration with other forms of messaging) play a significant role in developing long-distance e-mail traffic projections. Specifically, these factors provide the trends necessary to estimate message numbers and sizes used in figure 2-58.

The growing interconnectivity of e-mail applications through wide area networks (WAN), public e-mail backbones, and the internet is a factor in the growth of e-mail long-distance traffic (Burns Spring 1992, 28-33). One of the drivers in the interconnection of e-mail systems is the implementation of X.400 standard-based equipment and software (Telecommunications August 1991). In 1984, the CCITT adopted the X.400 series of standards for message handling systems, and in 1988 updated the standard to include security and store and forward features. The X.400 series allows electronic messaging systems from different vendors to be developed around common parameters, permitting the systems to freely exchange information. A survey conducted by e-mail systems provider Softswitch on e-mail usage in the corporate environment indicated that about half of the users had X.400 gateways in place while 75 percent of the remaining users plan to install them during the next 2 years (Telecommunications November 1991). There is still no consensus on the X.400 standard. Critics of the standard argue that reasons for its slow implementation include that compliance with the standard is not enough to guarantee that products from different vendors will work together (Saunders and Heywood 1992, 74). The increase in e-mail connectivity is estimated to have a significant effect in the 1994 to 2011 time frame.

Directory availability is another factor affecting the growth of electronic mail. Implementation and wide availability of X.500-based services will allow users to send mail to a person found in the directory without knowing the specific mail routing address of the addressee. X.400 standards provide for standard addressing but do not specify the directory services that are required to translate descriptive user names into network addresses. Conceptually, X.500 calls for a single, global telecommunications directory distributed across many networks but accessible by everyone. X.500 implementation may affect e-mail growth as early as 1996 continuing through to the end of the study period.

Integrated application development is another factor feeding the growth of e-mail applications. If e-mail applications are seamlessly integrated with other forms of office applications, the act of mailing across interconnected networks could be transparent to the user (Jenks 1992a, 27). Potential and existing applications include word processors, "groupware" such as Lotus Notes, project management software, databases (automated standardized forms), spreadsheets, publishing systems, and Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) software (Jenks 1992b, 27). These types of applications exist and are projected to have a measurable effect on e-mail in the 1995 to 2011 time frame.

The likely integration of e-mail with other types of messaging and information exchange makes it difficult to separate the potential traffic of different applications like fax, EDI, voice messaging, and paging services (Jenks 1992c, 31). Regardless of which type of application dominates by the year 2011, the traffic currently represented and projected for e-mail will grow as a result of this integration. The integration of applications and services is seen to be a factor in the 1996 to 2011 time frame.

The factors that affect the growth of e-mail applications over the course of the study are summarized in figure 2-59.

FIGURE 2-59
Summary of E-mail Factors

Factor	Duration of Effect
Interconnectivity	1994 - 2011
Directory Availability	1996 - 2011
Integrated Application Development	1995 - 2011
Integration with Other Forms of Messaging	1996 - 2011

Source: Booz-Allen Analysis

2.4.4 Terminal Operations

Terminal Operations is defined for this study as general terminal-to-computer and computer-to-computer traffic. Traffic projections for this broad category are used to capture traffic demand for general computing applications and make order of magnitude and relative growth comparisons with other data categories studied.

It is useful to examine how this category was handled in the previous NASA demand assessments because of the lack of widely available data on the demand components of this category. When IT&T looked at computer traffic in its study, they divided demand into two categories:

- Terminal – Central Processing Unit (CPU) Traffic: Inquiry/response traffic involving access to computer files by remote terminals and remote access to computing resources as in time-sharing.

- CPU – CPU Traffic: Exchange of data between computers. This category was subdivided into distributed processing and EFT. (IT&T, U.S. Telephone and Telegraph Corp. 1983, vol. 2). EFT is discussed in section 2.4.8.

Western Union defined terminal operations based upon the kinds of data transfer performed by the kinds of terminals in existence at the time of their study:

- Data transfer
- Batch processing
- Data entry
- Remote job entry
- Inquiry response
- Timesharing (Western Union 1983, Vol.2).

Several new, related trends in business environment computing affect our projections of terminal operations traffic demand. These trends include the following:

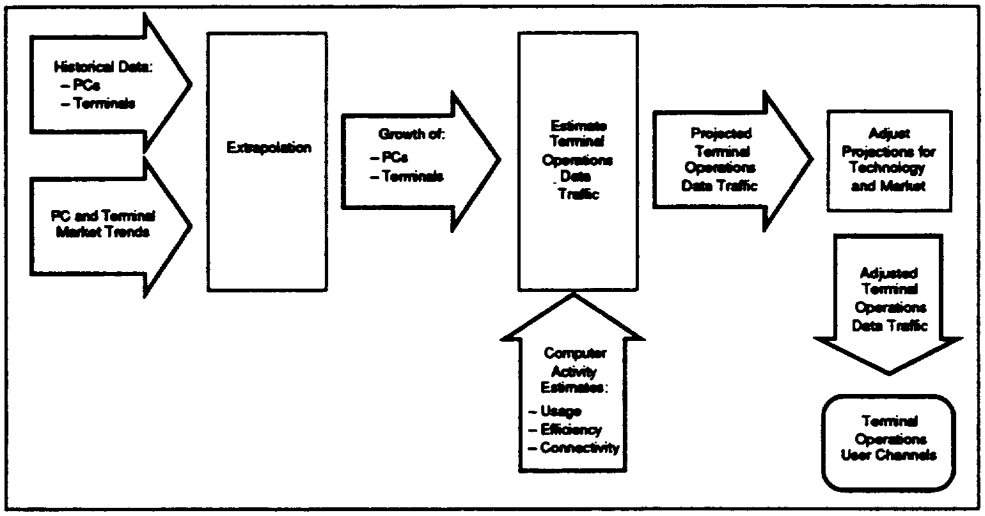
- Penetration of personal computers in the workplace
- Increased connectivity of PCs using local area networks
- Corporate downsizing of host-based computing (mainframe and minicomputers)
- Popularity of client server computing architectures
- Future implementation of true distributed processing computing environments.

These trends point to an updated view of the corporate computing model and the major elements of demand for computer communications using long-haul telecommunications networks. In addition to host-to-host bulk data transfer, this computing model describes the four kinds of computer communication that are currently dominant and will shape the future of the demand for telecommunications. The four components of this model are host-based, shared resource, client server, and true distributed (Gildea 1991, 3).

The host-based computing architecture is the oldest model and makes up most of the demand addressed in the terminal operations category of the previous studies. The shared-resource model developed with the emergence of LANs and the use of shared files, servers and printers. The shared-resource model, being predominantly LAN-based, is not addressed as a component of long-distance communications demand. The client server model, based on LAN/WAN interconnectivity, connects workstations to intelligent database servers that process requests for data through interprocess communication protocols. The end result of this increasingly popular architecture is reduced network traffic and increased processing efficiency. The distributed processing architecture relies on a network of interconnected computers performing integrated computations and is predicted to be the next evolution in computing architecture. As a result of the changing computing architectures that have been discussed, our study takes these computing models into account when making projections of terminal operations traffic.

2.4.4.1 Method. Terminal operations traffic projections are made based on the historical growth of PCs and terminals in addition to usage estimates calculated in previous NASA studies (IT&T, U.S. Telephone and Telegraph Corp. 1983, vol. 2). The historical data describing the installed base of PCs and terminals are extrapolated to obtain a projected number of computers involved in data communications. This number of terminals and computers is multiplied by terminal data transfer estimates to obtain projections of total terminal operations data traffic. These baseline projections are then adjusted for technology and market considerations. A summary of the process used in projecting terminal operations data traffic is shown in figure 2-60.

FIGURE 2-60
Terminal Operations Data Flow Diagram



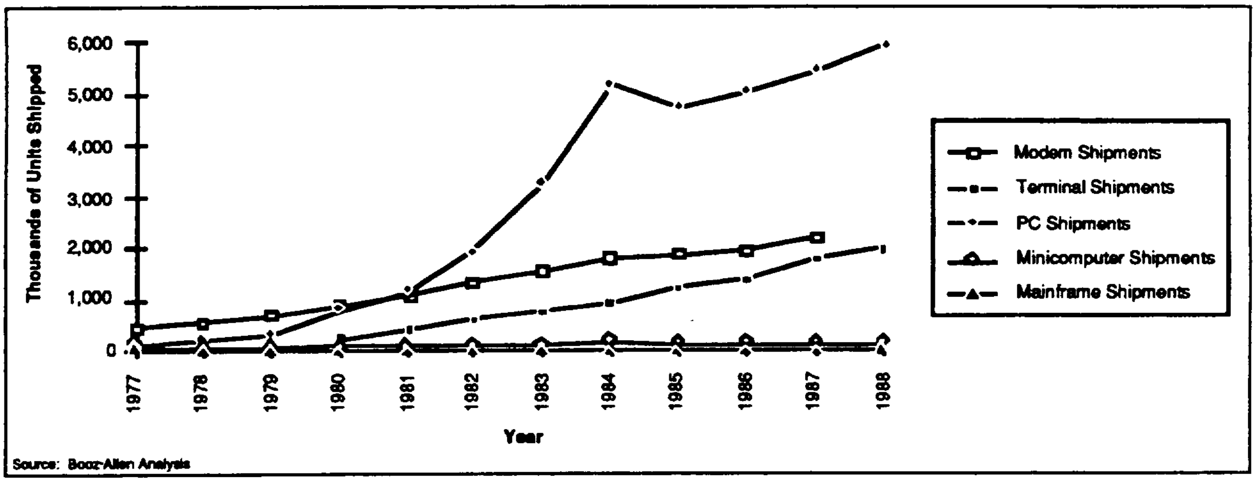
2.4.4.2 Baseline Projection. Data for estimating the growth of terminal operations traffic are obtained from several sources of modem, terminal, and computer shipments (CBEMA 1990, 93-104; U.S. Bureau of the Census 1990, 943-953). The data used as the baseline for data communications traffic generated by terminal operations are shown in figure 2-61. The chart in figure 2-62 shows the growth of the component data used for terminal operations traffic projections.

FIGURE 2-61
Computer Market Shipments 1977 – 1988 (Thousands of Units)

Year	Modem Shipments	Terminal Shipments	PC Shipments	Minicomputer Shipments	Mainframe Shipments
1977		470	120	57	9
1978		580	238	68	8
1979		700	329	81	7
1980	250	870	796	96	10
1981	420	1,105	1,157	102	11
1982	600	1,330	1,950	109	11
1983	770	1,550	3,249	117	10
1984	960	1,830	5,190	170	11
1985	1,220	1,850	4,750	154	11
1986	1,380	1,950	5,060	143	11
1987	1,810	2,230	5,460	146	11
1988	2,020		5,990	160	11

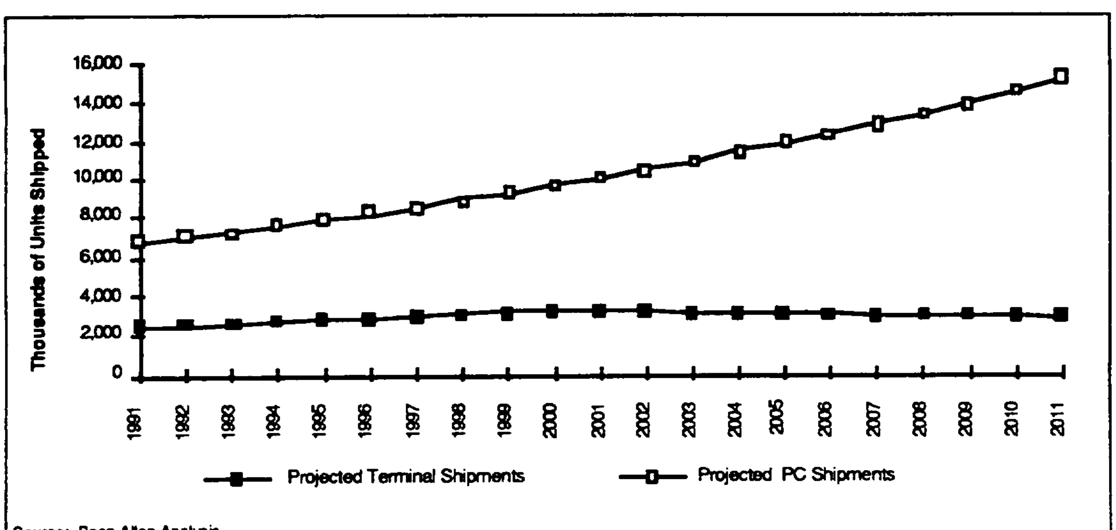
Source: CBEMA 1990
U.S. Bureau of the Census 1990

FIGURE 2-62
Terminal Operations Component System Growth



Extrapolations of the historical shipment data for terminals and PCs through 2011 provide the basis for terminal operations data traffic estimations. A terminal market growth of 2.8 percent (CBEMA 1990, 93-104) through 2000 and a market decline of 1 percent per year thereafter are used for a baseline extrapolation. This growth rate takes into account the increased use of PCs and workstations for terminal emulation and client server computing. Growth in the PC market has dropped from double-digit growth in the past few years to a low of 4.1 percent for computer specialty stores (Rosenblatt 1992, 27-29). This conservative growth is used for a baseline projection through 2011. Projections of terminal and computer shipments are shown in figure 2-63.

FIGURE 2-63
Terminal and Computer Shipments Baseline Projections



A projection of the amount of data traffic generated by terminal operations is tabulated in the chart shown in figure 2-64. Terminal and PC populations are estimated by summing the shipments for the years prior to 1991. This calculation assumes that shipments prior to the years shown are obsolete or have been replaced. A 10 percent adjustment is used to account for retirements and replacements in the years covered in the study. Estimates for terminals and PCs with communication links are based on Gartner Group data listed in the 1990 *Statistical Abstract of the United States*. Total terminal (PCs and terminals) traffic is calculated using a representative yearly traffic estimate of 290 gigabits per terminal, which was developed in IT&T's study (IT&T, U.S. Telephone and Telegraph Corp. 1983, vol. 2).

FIGURE 2-64
Terminal Operations Traffic Projection (Thousands of Units)

Year	Projected Terminal Shipments	Est. Terminal Population	% Terminals Connected to LD	Terminals Connected to LD	Projected PC Shipments	Est. PC Population	% PCs Connected to LD or WAN-WAN	PCs Connected to LD or WAN-WAN	Total Number of LD Terminals	Total Terminal Traffic (Terabits/Yr)
1991	2,500	24,000	18	4,300	6,800	54,000	10	5,400	9,700	2,800
1996	2,900	25,000	18	4,500	8,300	63,000	20	13,000	17,500	5,100
2001	3,200	27,000	18	4,900	10,000	75,000	30	23,000	28,000	8,100
2006	3,000	29,000	18	5,200	12,000	90,000	40	36,000	41,000	12,000
2011	2,900	29,000	18	5,200	14,500	110,000	50	55,000	60,000	17,500

Source: Booz-Allen Analysis

2.4.4.3 Adjusted Projection. Our model for the estimation of terminal operations traffic already takes into account market and technological factors affecting the growth of terminals and PCs. These factors are summarized in figure 2-65.

FIGURE 2-65
Factors That Affect the Growth of Terminal Operations

Factor	Effect On Terminal Operations Traffic Estimation
Decrease in terminal use due to PC terminal emulation.	Growth rate of terminals is relatively flat.
Resurgence in terminal sales due to X-terminal popularity.	Increased growth of X-terminal sales help to counteract declining overall terminal sales.
Increased use of client-server architecture using networked PCs and workstations.	Increasing percentage of communicating PCs over the course of the study.
High growth rate of notebook PCs and other portable computers.	Important effect if these computers communicate via long-distance public, cellular radio, or packet-switched radio networks (Magidson 1992, 72)

Source: Booz-Allen Analysis

Additional factors that will affect the growth of computing and terminal operations traffic in the future include the following:

- Standardized open systems
- Pen-based computing, integrated circuit memory, and input/output cards
- Multimedia standardization: digital audio, full-motion movie quality video (Rosenblatt 1992, 27-29)

2.4.5 Application/Industry-Oriented Data Applications

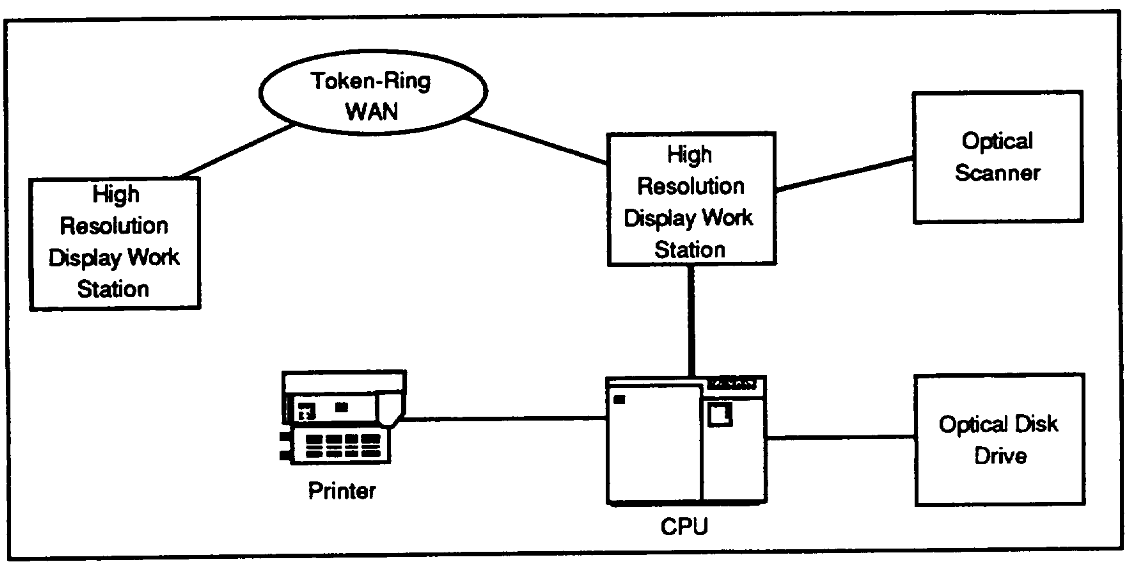
The application/industry-oriented data traffic category includes imaging, on-line information services, EFT, EDI, and research networks. This category describes the growth of applications whose growths are driven by their applications or industries.

2.4.6 Imaging

Imaging is a relatively new segment of the electronic data market involving storage, retrieval, and transmission of documents and illustrations in electronic form. This simple imaging architecture is shown in figure 2-66. The imaging category is a specialized subset of the more general terminal operations category. Even though we do not make projections for this category, we do look at the current state of the industry to estimate traffic size and future market potential.

Image processing applications require access to large amounts of information at rates acceptable to an increasingly demanding group of users. Even though it is possible to carry out image processing on general-purpose computers, it is more efficient to design specific hardware and software for image processing tasks. Imaging technology offers tremendous advantages over paper documents. Consequently, the market for imaging hardware, software, and services will exceed $5 billion in 1992 (Roger Sullivan, Wang Laboratories, Conversation).

FIGURE 2-66
Simple Imaging Architecture

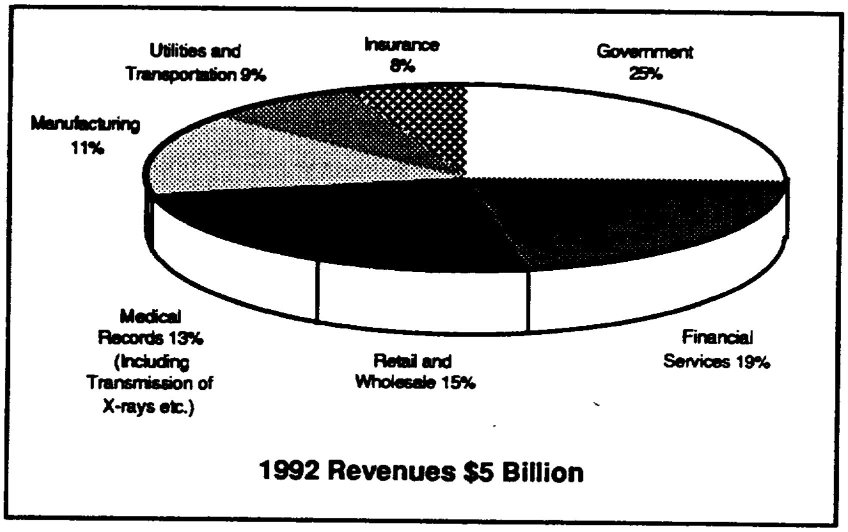


Some of the advantages of imaging include the following:

- Instantaneous retrieval
- Simultaneous display
- Rapid transmission
- Database capabilities
- On-line modifications.

The current worldwide market for document automation is split among several industries. Figure 2-67 summarizes this market breakdown.

FIGURE 2-67
Current Worldwide Image Market for Documentation Automation



Source: Roger Sullivan

2.4.6.1 Method. Imaging systems can be either stand-alone or distributed. Only distributed systems that cover a large geographic area generate long-distance traffic. We estimate the total long-distance traffic generated in 1990 by transmission for imaging systems. Because imaging is in its infancy in terms of companies and industries trying it and deciding which applications are suitable, it is impossible to predict how widespread it will become. Only about 1 to 2 percent of document storage and retrieval now requires long-distance transmission. Without knowing something about future applications, whether this fraction will change, and in what direction, is also impossible to estimate. A third area of uncertainty is how much progress will be made in data compression technology. For all these reasons, we do not consider imaging traffic in our totals.

2.4.6.2 Current Status. With current compression technology, a scanned 8.5 inch by 11 inch text document produces a file size of between 50 and 100 thousand bytes. Graphic displays may be 10 to 20 times larger. Typical image sizes using compression are summarized in figure 2-68 (Edelstein November 1991, 96-100).

FIGURE 2-68
Typical Image Sizes Using Compression

Resolution	Uncompressed File Size	90% Compression	95% Compression
200 DPI	1 Million Bytes	100,000 Bytes	50,000 Bytes

Source: Edelstein November 1991

Historical data on imaging transmission are generally unavailable. As a surrogate, relationships were developed among a number of available factors and a derived series was produced (Assoc. for Info. & Image Management 17 January 1992). As a result of this analysis, the chart in figure 2-69 displays trends that describe the growth in image processing. In this figure, a document is one 8.5 inch by 11 inch page.

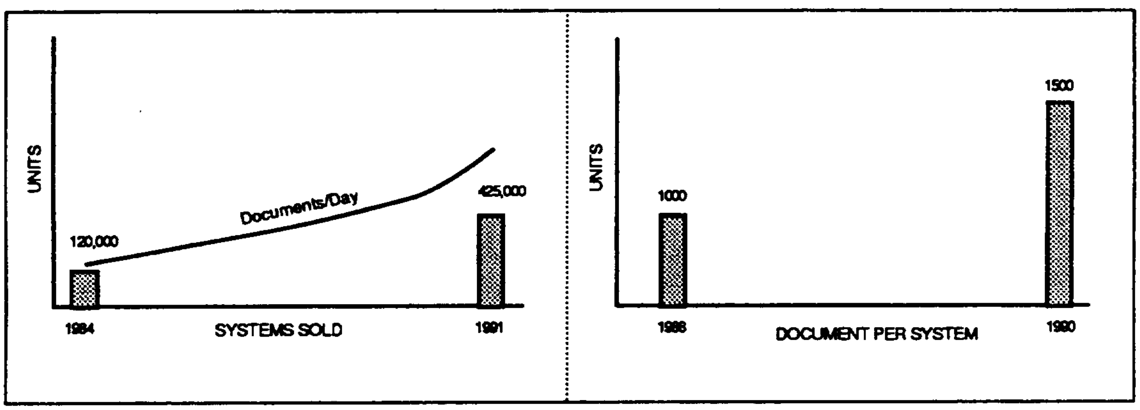
FIGURE 2-69
Historical Growth in Image Processing

Year	Imaging Systems Sold	Daily Document Volume	Percent WAN/LD	Transmission Volume (Doc/ Day)
1988	120,000	1000	1 %	1.2 Million
1990	425,000	1500	2 %	12.7 Million

Source: Assoc. for Info & Image Management 17 January 1992

Historically, there has been a clear relationship between the number of imaging systems sold and imaging transmission volume (Assoc. for Info. & Image Management 17 January 1992). Volume has also greatly increased over the period. These trends are shown in figure 2-70.

FIGURE 2-70
Trends in Imaging Transmission



Source: Assoc. for Info and Image Management 17 January 1992

The primary factors influencing the growth of imaging transmissions are declining equipment cost (particularly document conversion and storage), bandwidth availability, and compatibility with other applications. These factors are summarized in figure 2-71.

FIGURE 2-71
Summary of Imaging Transmission Factors

Factors	Impact	Duration of Effect
FDDI, FDDI-11 Stimulating Fiber-Based LANs and WANs	Bandwidth Availability	1992 - 1997
Improved Storage Devices (Mini-Optical Jukeboxes)	Reduced Storage Costs	1992 - 2000
Database Software	Improved Indexing and Retrieval Capabilities	1992 - 1995
Linkage to other Applications (e-mail, CAD, Fax)	Increased Versatility, Improved Transmission Capabilities	1992 - 2006

Source: Booz-Allen Analysis

2.4.6.3 Projections. The numbers presented in figures 2-70 and 2-71 give a total long-distance transmission volume for imaging of about 5000 gigabits per day. This is about half the volume of terminal-operations traffic but much large than other present sources of data traffic quantified in this report. An unknown amount of imaging traffic was already considered in terminal operations, since the total number of terminals was counted there. Therefore, the 1990 imaging transmission volume is probably less than 5000 gigabits per day. As an exercise, this can be projected to 2011 using assumed annual growth factors. Compounded growth at 3 percent or 5 percent per year would give 9000 or 14,000 gigabits per day. While these are large numbers, when converted to busy-hour DS0s, they are a negligible fraction of the MTS voice traffic.

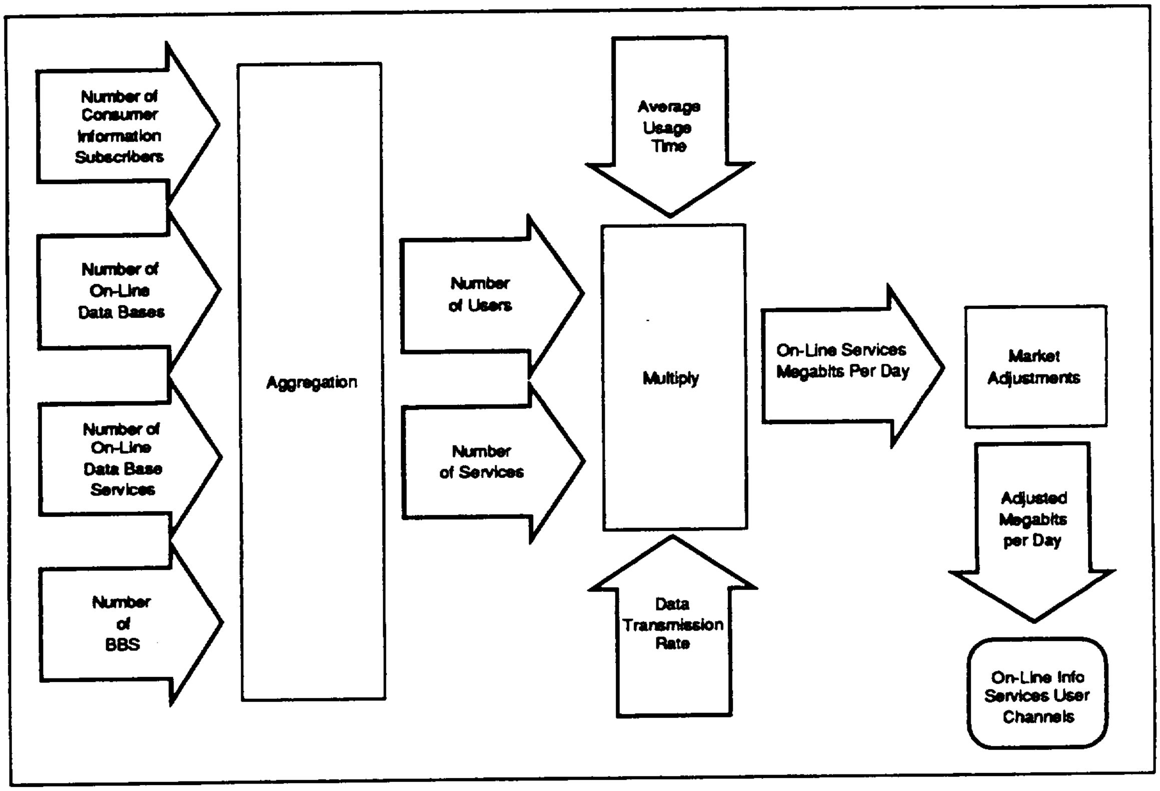
2.4.7 On-line Information Services

On-line information services (OLIS) are considered to be any terminal-to-host communication that uses consumer information services, on-line database and/or research services, or bulletin board systems (BBS). OLIS bring together computer, communications, and text-based resources, allowing individuals and businesses to access vast libraries of information and services easily.

Consumer information services include Compuserve, GEnie, the Source, America On-line, Prodigy, and others. On-line database and research services include DIALOG, Dow Jones News/Retrieval, Mead Data Central, Pergamon ORBIT Infoline, and Reuters. Bulletin board systems are small providers of dial-up services in comparison to the other categories. The BBS category includes local specific interest user groups as well as commercial on-line help services.

2.4.7.1 Method. Long-distance traffic for on-line information services is forecasted based on historical information on the number of services and their subscribers. This historical information includes data on the number of subscribers and the number of database, BBS, and on-line services. Research and analysis provides information on the average number of transmissions per day and the average megabits transmitted per session. These inputs are used to estimate the total amount of megabits per day generated by on-line information systems. These estimates are projected using s-curve techniques to forecast the future demand for on-line information service traffic in this market. The final step is to adjust our forecasts with effects that are not inherently apparent in the analysis performed in the previous step. A summary of this process is shown in figure 2-72.

FIGURE 2-72
On-Line Information Services Data Flow Diagram



2.4.7.2 Baseline Projection. Our data consist of the number of subscribers and the number of services available in the on-line information services market. These data are summarized in figures 2-73 (Barnes 1991 1-13; International Resource Development Inc. 1988), 2-74 (Information Hotline May 1985, 17:1), and 2-75 (Barnes 1991, 1-13). The data were not inclusive, so extrapolation techniques were used to determine data that were not available. Additionally, it is assumed that approximately 90 percent of the Dow Jones subscribers also subscribe to another service.

FIGURE 2-73
Computer Information Service Subscribers

Service	1988	1991 Estimated	1992 Estimated
Compuserve	400,000	600,000	700,000
GEnie	100,000	166,000	200,000
The Source	70,000	100,000	115,000
Prodigy	0	250,000	500,000
Videotex	700,000	1,000,000	1,150,000
Dow Jones	256,410	300,000	351,000
Total	1,300,000	2,150,000	2,700,000

Sources: Barnes 1991; Intemaitonal Resource Development Inc. 1988

FIGURE 2-74
On-Line Database/Research Services

	1979	1984	1992
On-line Databases	400	2453	6000
On-line Database Services	59	362	4700

Source: Information Hotline May 1985

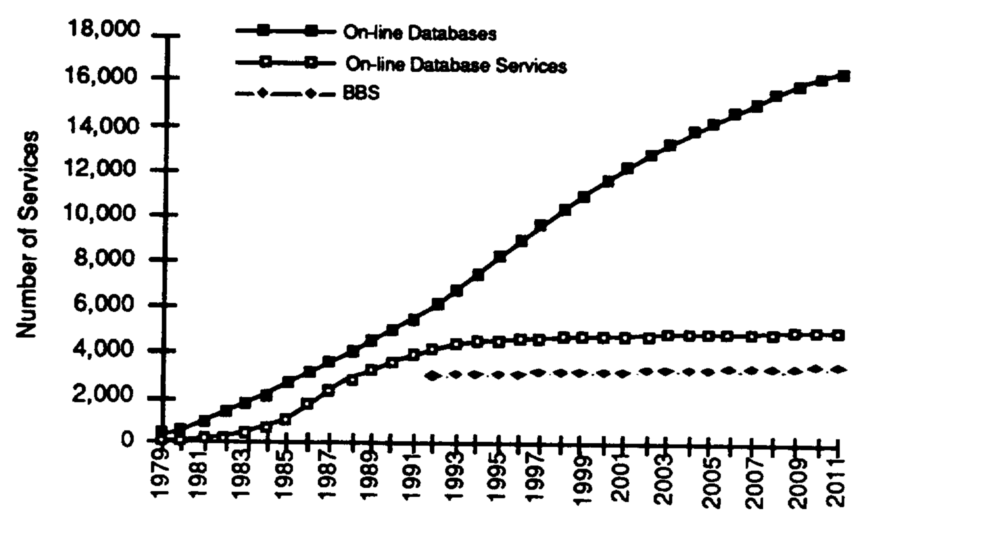
FIGURE 2-75
Bulletin Board Systems

	1992
Bulletin Board Systems	2000-4000

Source: Barnes 1991

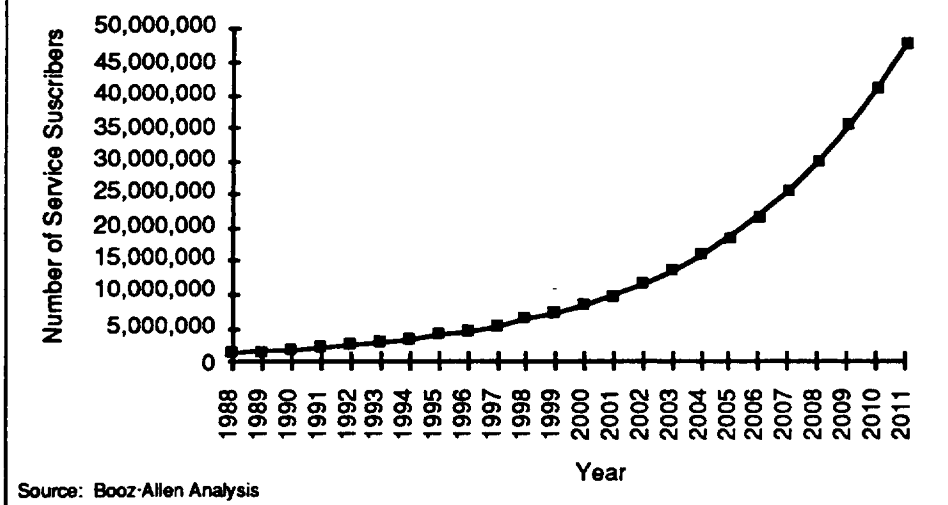
The historical data indicate that the megabits transmitted for on-line services is a function of the services available and the number of subscribers. These trends are shown in figures 2-76 and 2-77. Furthermore, we estimate the number of daily transmissions based upon the number of databases available in the market. Our data ultimately consist of the number of users, average number of transmission per day, and the average number of megabits transmitted per session.

FIGURE 2-76
Forecasted Number of Services Offered to Users



Source: Booz-Allen Analysis

FIGURE 2-77
Forecasted Number of Consumer Information Service Subscribers



Source: Booz·Allen Analysis

Using the information summarized in above mentioned figures, we are able to calculate the total megabits transmitted per day. This calculation is shown in figure 2-78. The average number of transactions used in the table is a function of the number of databases available. The average number of megabits transmitted per year are estimates based on Booz·Allen analysis. An s-curve is used to project the future demand for OLIS traffic. (See figure 2-80.)

FIGURE 2-78
Estimate of the Number of Megabits Transmitted Per Day for OLIS

Year	Number of Users (Millions)	Databases Available	Average Number of Transmissions/Day Per User †	Average Megabits Per Transmission	Megabits Per Day
1991	2.1	5,700	.30	.02	12,500
1996	4.6	9,200	.48	.02	44,000
2001	10.0	12,000	.64	.02	130,000
2006	22	15,000	.77	.02	340,000
2011	48	16,000	.87	.02	840,000

† Average number of transactions is assumed proportional to the number of databases available
†† These numbers are an estimate based upon Booz·Allen analysis
Source: Booz·Allen Analysis

2.4.7.3 Adjusted Projection. There are many factors that may affect the growth of on-line information services:

- Diversification of services
- Integration of on-line information services into everyday use
- System usability
- Telecommuting
- New transmission media.

Currently, on-line services are difficult to use and understand. As long as this is the case, on-line information services will not be used very often. Therefore, we considered this factor to cause a 5 percent decrease in the projected growth through 2000.

The greatest impediment to growth in on-line information services is their integration into day-to-day business operations and personal life. While these services offer more convenient access to information, they do not offer new information or provide new ways of doing business. This tends to slow the diffusion of these services into business. We assume this will cause a 7 percent annual decrease in growth until 2005.

The impact of the RBOCs in this market may help alleviate both of the above problems at a pace faster than expected. As companies are able to offer new and better services to subscribers the market will be competitive and the services cheaper. The competition will entice more people to join and use these services and will thus create a 1 percent increase in our forecasts from 1996 to 2006.

As more people choose to work at home the demand for information services will increase. Working at home will remove the access to copious amounts of information now available to large industries. The way to alleviate this problem will be to use on-line information services through telecommunications. Thus this will provide a 2 percent increase in growth from 1996 to 2005.

Higher bandwidth offered by fiber optics will allow on-line information services to offer better, higher quality, and easier-to-use services. This will increase the usability and the integration of these services into the home. Furthermore, it will increase the number of new services offered by these companies. Thus we expect an increase of 1 percent growth from 1998 to 2005.

The factors affecting the growth of on-line information services over the course of the study are summarized in figure 2-79. The adjusted projections of on-line information service traffic are shown in figures 2-80 and 2-81.

FIGURE 2-79
Summary of On-line Information System Factors

Factor	Effect on Baseline Projections	Duration of Effect
Diversification of Services	+1%	1996 - 2006
Lack of OLIS Integration Into Everyday Use	-7%	1993 - 2005
System Usability	-5%	1993 - 2000
Telecommuting	+2%	1996 - 2005
Fiber Optics	+1%	1998 - 2005

Source: Booz-Allen Analysis

Our forecast is affected heavily by the service providers' ability to provide easy-to-use systems that are convenient and adequately serve the subscribers' needs. The megabits transmitted by on-line information service users will be greatly affected by the providers' ability to integrate their services with their customers.

FIGURE 2-80
Adjusted Growth of OLIS Traffic

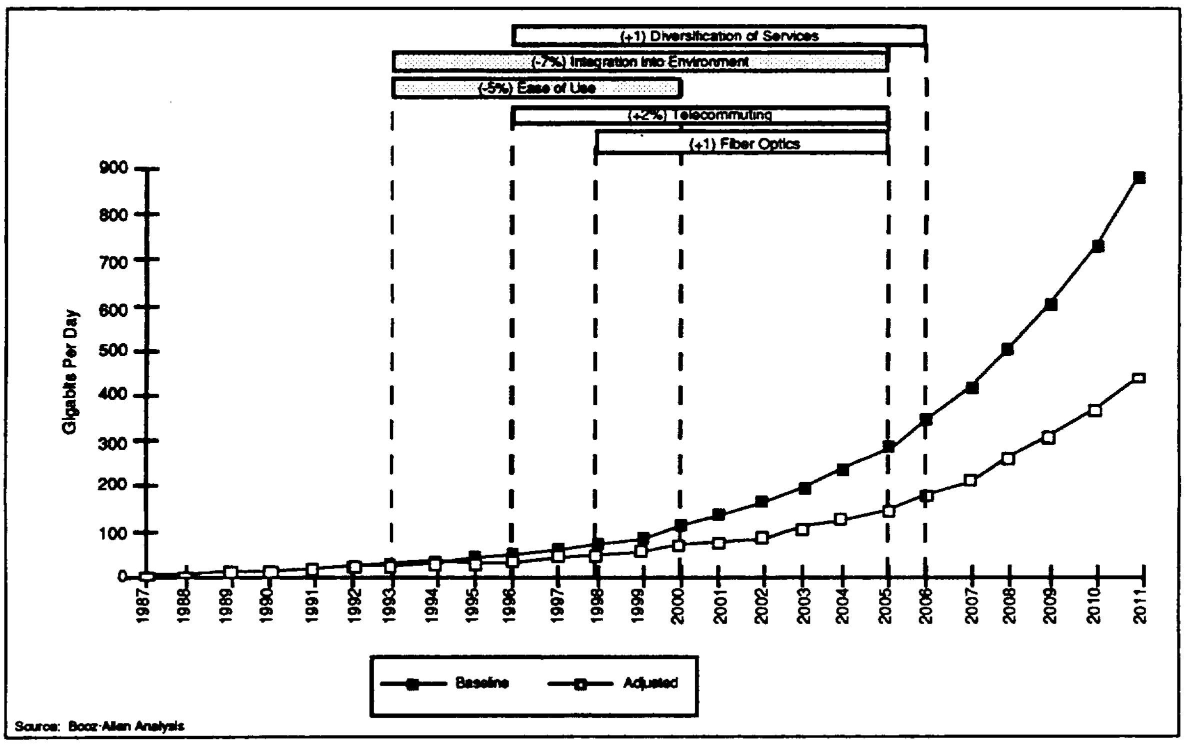


FIGURE 2-81
Adjusted Projections of OLIS Traffic

Year	Baseline OLIS Projection (Gigabits/Day)	Adjusted OLIS Projection (Gigabits/Day)
1991	12.5	12.5
1996	44	33
2001	130	72
2006	340	170
2011	840	420

Source: Booz·Allen Analysis

2.4.8 Electronic Funds Transfer

EFT is a system that transfers money electronically among organizations' accounts without the physical transfer of documents. EFT primarily provides three services: interbank transactions, wholesale transactions, and retail transactions. The main features of these services are:

- Interbank transactions
  - Automated Clearing House
  - Wire networks (Fedwire, Chips, Swift II)
  - Electronic check truncations

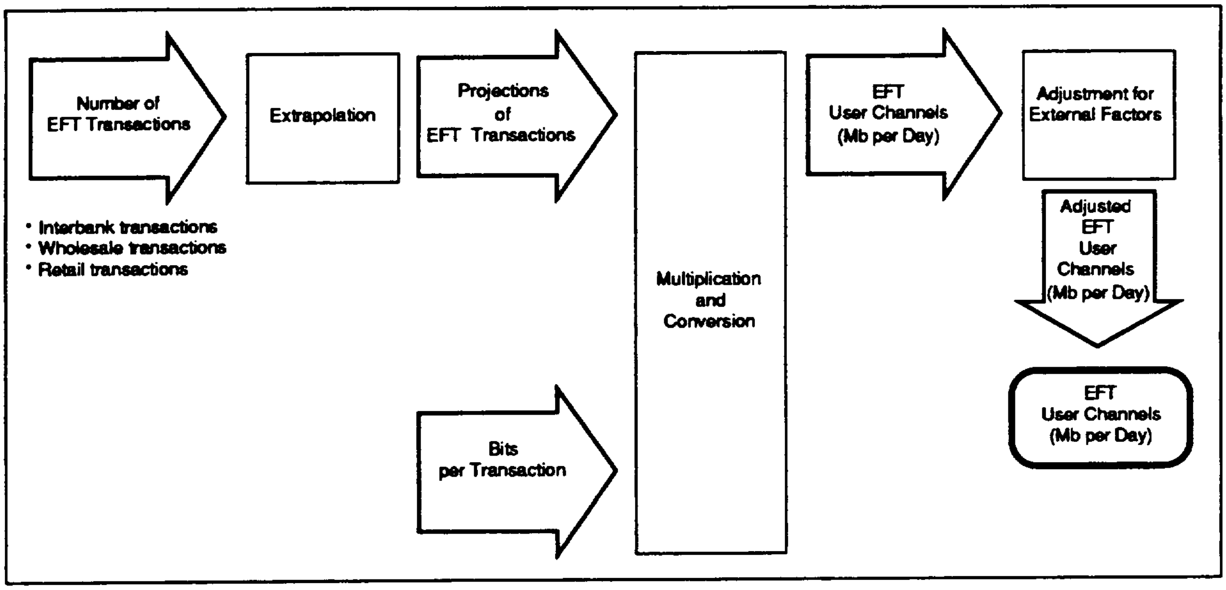
- Wholesale transactions
  - Direct deposit
  - Corporate trade payments

- Retail transactions
  - Electronic bill payments
  - Automated Teller Machines
  - Point of sale (POS) systems/debit cards.

The use of EFT carries several advantages. EFT ensures accuracy, increases transaction speed, reduces storage requirements, and allows for the printing of transaction records.

2.4.8.1 Method. EFT traffic projections are based on historical EFT transactions for the primary EFT services converted to user channels and adjusted through the introduction of external factors. Figure 2-82 summarizes this process.

FIGURE 2-82
EFT Data Flow Diagram



2.4.8.2 Baseline Projection. Interbank electronic funds transfer generally refers to a funds transfer used to satisfy an immediate, high-dollar obligation, or to enable the recipient to make immediate use of funds. This process is shown in figure 2-83. Figure 2-84 describes the three primary wire systems: Fedwire, CHIPs, and SWIFT (GAO February 1989).

FIGURE 2-83
INTERBANK EFT

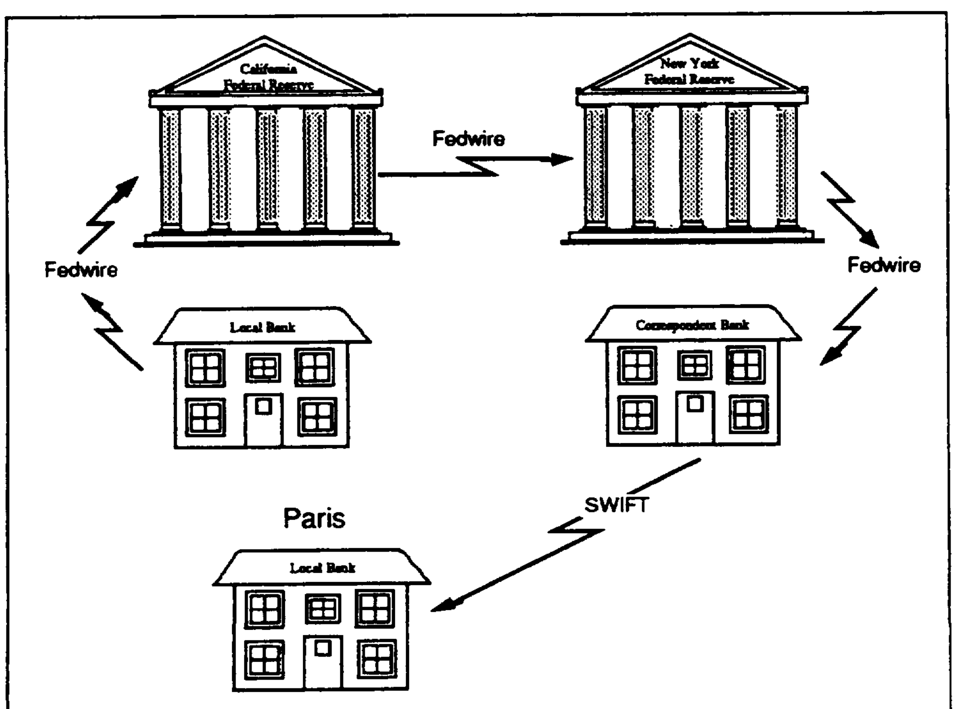


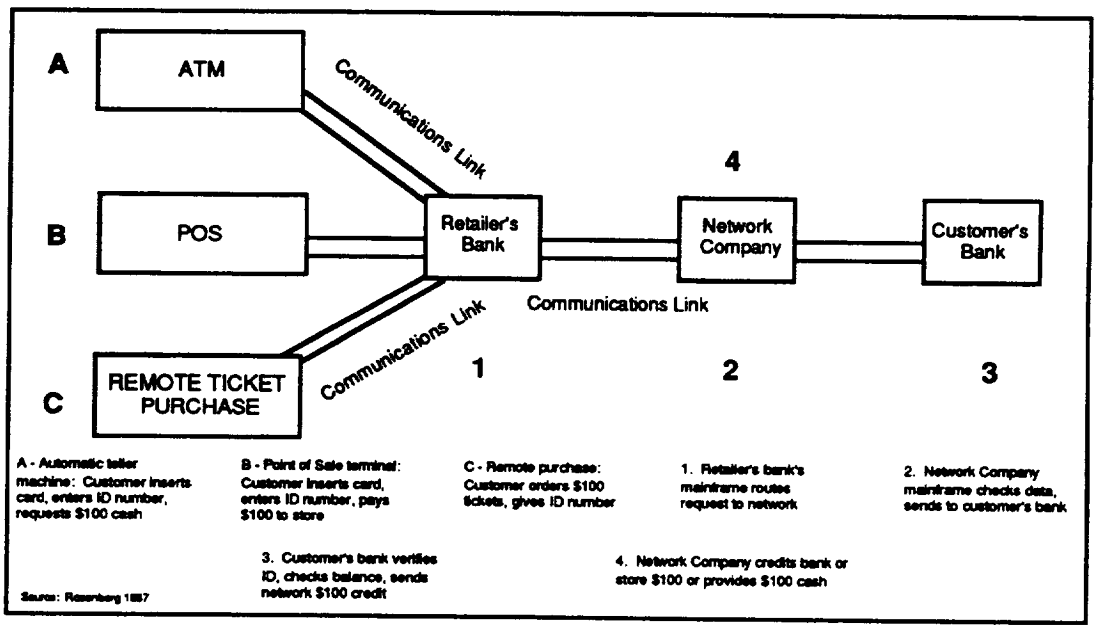
FIGURE 2-84
EFT Interbank Transfer Primary Wire Systems

System	Participants	Daily Transactions
Fedwire	12 federal banks, 25 branches, U.S. Government agencies, 10,000 depository agencies	55 million
CHIPs	138 domestic depository institutions and branch offices of foreign banks all located in New York City	32 million
SWIFT	2,360 institutions in 56 countries	1 million

Source: GAO February 1989

Typical retail transactions require a customer interface, a network routing system, and a communications network. Figure 2-85 shows typical retail systems (Rosenberg 1987, 37).

FIGURE 2-85
Typical Retail EFT System



The size of the EFT market can be estimated by examining the historical daily transactions for the primary EFT services. Figure 2-86 summarizes the historical data collected (GAO, February 1989, Rosenberg 1987, 37, POS News September 1990, 3, Consumer Trends 5 February 1990, Elbert).

FIGURE 2-86
Historical Daily EFT Transactions

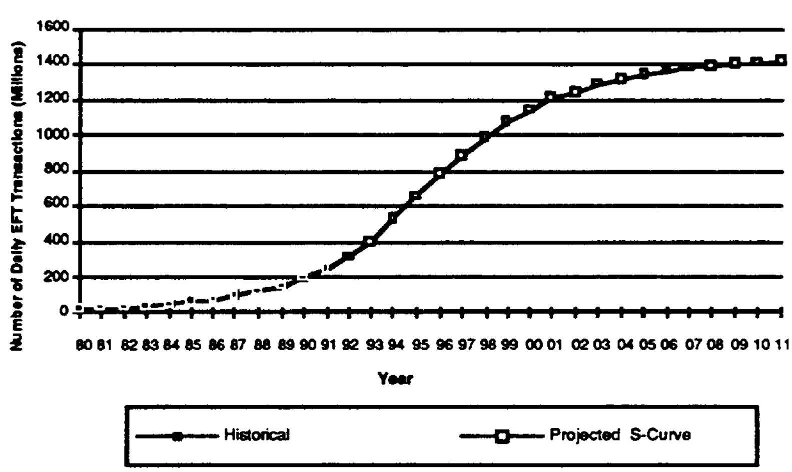
Year	Interbank Transactions: Fedwire	Interbank Transactions: CHIPS	Interbank Transactions: SWIFT	Wholesale Transactions	Retail Transactions: ATM	Retail Transactions: POS
1980				5,500,000		
1981					120,000	
1982						
1983						
1984	22,000,000	16,000,000				
1985						
1986			780,000		1,700,000	
1987	55,000,000	32,000,000	1,000,000			
1988						
1989						344,440
1990				38,000,000		436,000
1991						

Sources: GAO February 1989
Rosenberg 1987
POS News September 1990
Consumer Trends 5 February 1990

Based upon an aggregate projection of total EFT transactions, an s-curve is used to forecast EFT transactions through the year 2011. The s-curve method is used here to model the effect of new technology on the ability to transfer funds electronically. Specifically, the growth of fiber-based transmission media and the spread of POS devices and personal electronic banking are seen as market growth factors through the year 2000. The s-curve projects the growth in transactions per U.S. resident per day from about 0.8 in 1990 to about 4 in 2011. The s-curve shown in figure 2-87 reflects this analysis. Using an estimate of .01 megabits per EFT transaction, a projection of the daily EFT traffic requirements is developed. Calculations are shown in figure 2-88.

FIGURE 2-87
Baseline EFT Projection

Year	Daily Transactions (Millions)	Year	Daily Transactions (Millions)
1980	27	1996	780
1981	30	1997	890
1982	34	1998	990
1983	40	1999	1100
1984	50	2000	1150
1985	65	2001	1200
1986	80	2002	1250
1987	102	2003	1300
1988	126	2004	1300
1989	156	2005	1350
1990	*200*	2006	1350
1991	*260*	2007	1400
1992	*320*	2008	1400
1993	*400*	2009	1400
1994	*530*	2010	1400
1995	*660*	2011	1400



Source: Booz-Allen Analysis

2.4.8.3 Adjusted Projection. EFT growth over the study period will be influenced by technological advances, legislative activity, proliferation of terminal equipment, and consumer acceptance. The effects of these factors are summarized in figure 2-89.

FIGURE 2-88
EFT Daily Channel Requirements

Year	Number of EFT Transactions per Day (millions)	Megabits/ Transaction	Total Daily EFT Megabits (millions)
1991	260	.01	2.6
1996	810	.01	8.1
2001	1400	.01	14.0
2006	1600	.01	16.0
2011	1650	.01	16.5

Source: Booz·Allen Analysis

FIGURE 2-89
Summary of EFT Factors

Factor	Effect on EFT Growth	Duration of Effect
Relaxations of banking regulations allowing for interstate banking	+1%	1994 - 2001
Proliferation of POS terminal equipment	+1%	1996 - 2001
Consumer acceptance of paperless transactions	+1%	1994 - 1999

Source: Booz·Allen Analyses

By applying external factors to our baseline EFT transactions forecast, an adjusted projection of EFT usage through the year 2011 is developed. These projections are shown in figures 2-90 and 2-91.

2.4.9 Electronic Data Interchange

The basic principle of EDI is that computer-generated trading documents, such as orders and invoices, are transmitted directly to a company's trading partners' computers across a telecommunications network. The term trading partners is used to describe any company, government department, or commercial or noncommercial entity with whom an organization regularly exchanges documents containing formatted data (i.e., not just memos or letters) as a normal consequence of carrying out business or governmental functions.

FIGURE 2-90
Adjusted EFT Transaction Growth

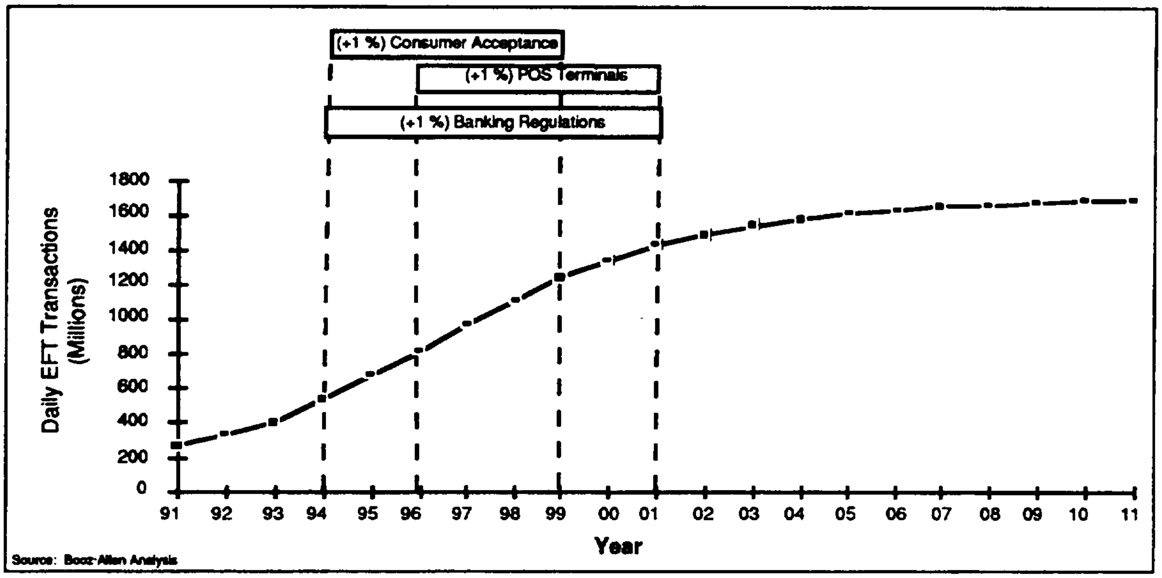


FIGURE 2-91
Adjusted EFT Transaction Projections

Year	Number of EFT Transactions per Day (millions)	Megabits/ Transaction	Total Daily EFT Megabits (millions)
1991	260	.01	2.6
1996	810	.01	8.1
2001	1400	.01	14.0
2006	1600	.01	16.0
2011	1650	.01	16.5

Source: Booz·Allen Analysis

In practice, the typical EDI service comprises a communications network and a central mailbox service with software to translate and route formatted electronic data or EDI forms. In a typical EDI network there is a hybrid of direct computer-to-computer links between the major trading partners, although probably no more than five or ten participants communicate directly. The majority communicate by means of the EDI mailbox and a value-added network or third-party communications network of some type.

For EDI communications, leased lines are needed for high volume transmission principally over public X.25 packet-switched networks. Dial-up over the public switched network (PSN) is used for PC-based communications and smaller data volumes. Line charges are usually measured in minutes rather than hours. A variety of different access methods are already in use, including the use of proprietary protocols and 800 services.

The computer hardware needed for EDI includes a computer system on each trading partner's premises. Typically this is a PC, but for larger volumes a mainframe is used. Around 10 to 20 percent of EDI participants utilize mainframes or minis; the remainder, PCs. Modems and communications equipment are also needed.

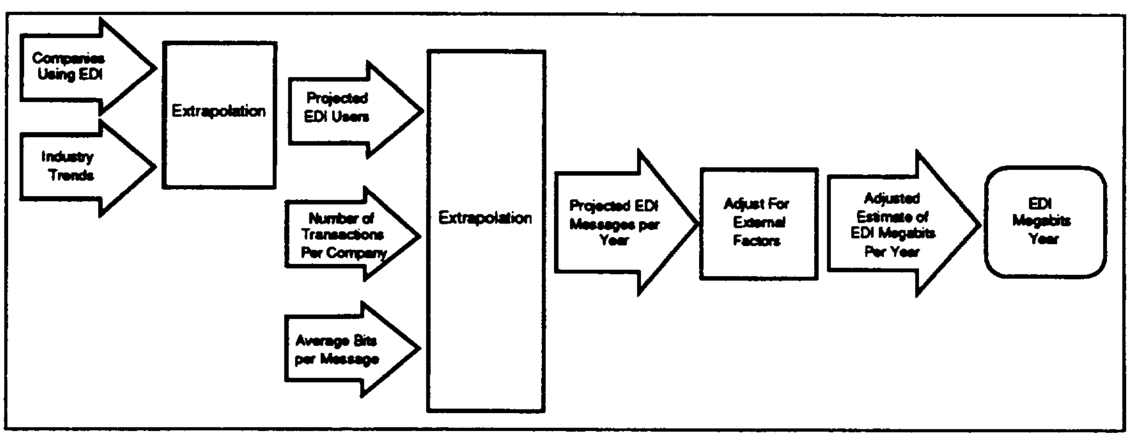
Direct benefits from EDI include the following:

- Easy access to information
- Time independence
- Paper reduction
- Error reduction
- Inventory reduction
- Improved customer relations
- Improved supplier relationships
- Broader trading horizon
- Increased velocity of trading.

EDI logically leads to new network services that enhance traditional ways of conducting business. These services include electronic mail, customer database systems, electronic software distribution, and EFT. EDI is not simply developing a paperless society; it enhances the way corporations do business.

2.4.9.1 Method. The telecommunication traffic generated from EDI is projected based on the historical number of companies who use EDI. This process is summarized in the data flow diagram shown in figure 2-92. Our analysis includes an examination of the usage patterns of small and large institutions. From this information we derive the average number and size in megabits of typical EDI messages per year. With this information we determine the average number of megabits transmitted per year for EDI.

FIGURE 2-92
EDI Data Flow Diagram



The s-curve analysis is used to reflect the potential for market saturation and the diminishing effects of a new product on the market. Once our baseline projections for the number of EDI user channels is determined we adjust these forecasts to reflect likely effects from external factors. This process enables us to predict final estimates that reflect the current trends as well as incorporate factors that are not present in the historical data.

2.4.9.2 Baseline Projections. In our research we found a wide disparity in the estimations of the number of companies using EDI. This is probably because the definition of EDI differs from person to person. EDI can include electronic funds transfers as well as electronic document transfers. This made it difficult to accurately assess the current EDI market. We averaged the high and low estimates for the number of EDI users to reflect this disparity in numbers. Figure 2-93 summaries the data collected for EDI users (Kimberly; Falkner Technical Reports Inc. 1991; International Resource Development April 1987; American Management Assoc., 15-20).

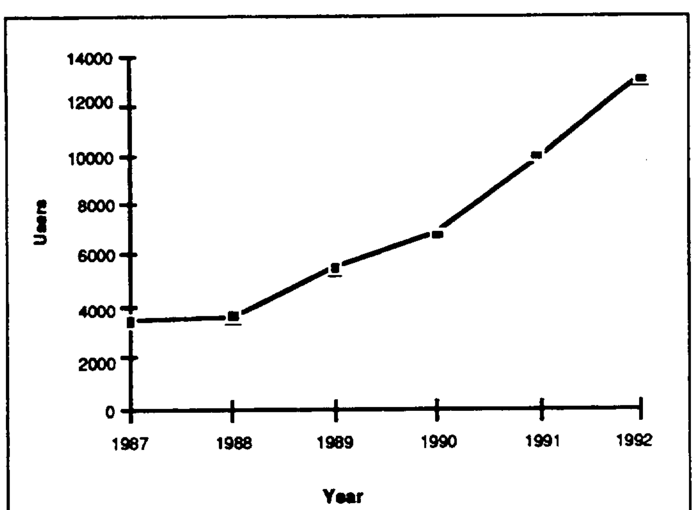
FIGURE 2-93
Estimated EDI Users

Year	Estimated Number of Companies Using EDI	Estimated Number of U.S. Companies Using EDI
1987	3500	3500
1988	3500 - 4000	3700
1989	5000 - 6000	5500
1990	6000 - 7000	7000
1991	9000 - 13,000	10,000
1992	13,000 - 17,000	13,000

Sources: Kimberly
Falkner Technical Reports Inc. 1991
International Resource Development April 1987
American Management Assoc.

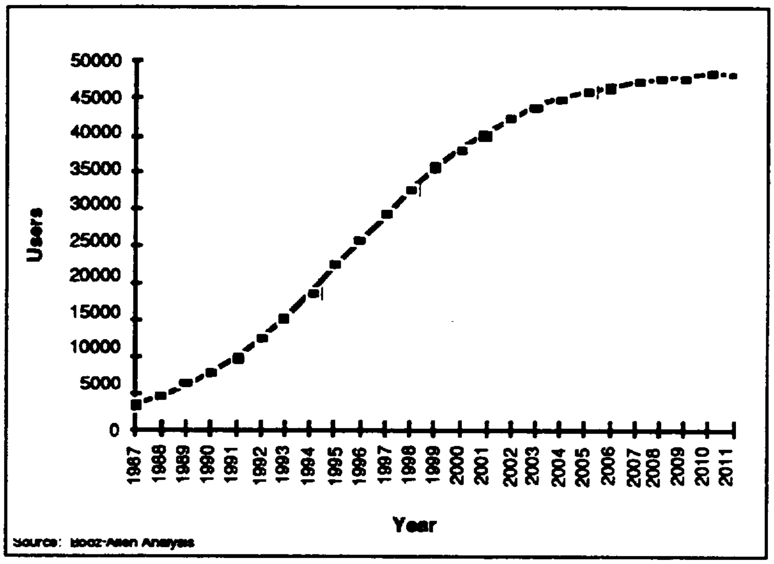
Figure 2-94 shows the growth of the EDI user base from 1987 to the expected population in 1992. Our initial data show that early growth of EDI was driven by large companies and their links to suppliers and customers. Over the next decade EDI use is expected to demonstrate high growth as smaller companies embrace new standards and fully implement EDI into their organizations. The results of our s-curve projection of EDI user growth is shown in figure 2-95.

FIGURE 2-94
Estimated Number of Companies Using EDI



Sources: Kimberly
Falkner Technical Reports Inc. 1991
International Resource Development April 1987
American Management Assoc.

FIGURE 2-95
Baseline EDI User Growth



Using our projections of EDI users and information about the usage of EDI, the transmission volume can be calculated. The results are shown in figure 2-96. The following assumptions were used. One is the number of messages per company per year. This averaged 2,500 in the 1980s. We assume this remains constant over the study period. To convert messages per year to messages per day, we assumed that EDI volume on weekend days will be about half of the weekday volume. Based upon Booz·Allen analysis, an average message size of 10 megabits was used.

FIGURE 2-96
Baseline Projection of EDI Traffic

Year	Number of Companies Using EDI	Number of EDI Messages Per Day	Gigabits Per Day @ 10 Mb/msg
1991	10,000	80,000	800
1996	26,000	210,000	2,100
2001	40,000	320,000	3,200
2006	46,000	370,000	3,700
2011	48,000	380,000	3,800

Source: Booz·Allen Analysis

2.4.9.3 Adjusted Projection. The potential growth for EDI is heavily dependent on external factors. The following paragraphs discuss several of these factors. Factors that are potential inhibitors of EDI are discussed first, then factors that could spur EDI growth are discussed.

A potential inhibitor to the growth of EDI is the status of telecommunications regulations. In virtually every economically developed country, the government has either announced or has already implemented a deregulated telecommunication system. On the other hand, some have announced deregulation but have not yet really changed the rules. This hiatus exists worldwide, nowhere more so than in the United States where several of the RBOCs complain the United States will be relegated to the status of a lesser-developed telecommunications country if the rules are not rewritten to allow them to directly provide value-added services. Regulatory issues are estimated to have a -2 percent effect on EDI growth for the 1991-1996 time period.

The state of EDI knowledge in the marketplace is a factor preventing the growth of EDI. The source of knowledge for intending and existing EDI users is gradually being filled as commercial interests fill the education vacuum. However, in general, they tackle only the technical issues; the fundamental issues regarding changes of business practice, legal and commercial questions, and thos factors surrounding the services that follow and complement EDI are still underexplained and unclear. This factor causes a -2 percent adjustment to the baseline projection for 1991-1996.

Another issue affecting the growth of EDI is the question of security. The major question is what if a document ends up on a competitor's desk? EDI is not yet viewed to be an extremely secure technology. Companies will have a difficult time transmitting sensitive order information over public networks. Once this problem has been overcome, EDI has the potential to demonstrate greater growth. Thus, this introduces a negative factor from 1991 to 1996 of -1 percent.

One factor that will prevent the immediate growth of EDI is the lack of awareness by businesses that, by interconnecting processors for the purposes of common interest applications, trade groupings, industry groupings, or plain common user applications, they can save time, money, space, administration, and staff. Businesses have not yet realized the advantages of the paperless society. It is and will be very difficult to change these attitudes about such major fundamental ways in which they do business. Once companies realize this the growth will be more dramatic. We do not expect companies to make this type of fundamental change until 1996. Thus this will have a -3 percent effect on the growth of EDI from 1991 to 1996.

Advances in interconnection and systems integration methods are a factor affecting the growth of EDI. Developments in IBM interconnection techniques in particular are increasingly making it easier to interconnect many different processors and introduce previously-impractical applications. EDI is developing because of a newly emerging series of innovations that allow different types of host processors to communicate via telecommunications networks, and because of the ability of individual end users to access networks from their own personal workstations. Newly emerging standards such as those from national article and product numbering authorities, from SITPRO, ANSI (American National Standards Institute), CCITT, ISO (International Organization for Standardization), and numerous trade bodies have been subsumed by ISO under the title EDIFACT (EDI for Administration, Commerce, and Transportation). ISO is absorbing all current EDI standards and codifying them on a time scale that harmonizes with X.400 (messaging) standards approvals. Protocol standardization, particularly progress on OSI and a wide acceptance of SNA (Systems Network Architecture) is also preparing the ground for EDI, although SNA principles make it difficult to adapt for X.25 application without expensive software being installed in IBM communication controllers. As standards are developed it will be easier and cheaper to acquire EDI software and services. This will increase user channel demand by 3 percent from 1993 to 1997.

The advent of new technology, computer driven networks capable of multiple protocol conversions and a variety of access methods, from asynchronous access to proprietary protocols, is another factor influencing EDI market growth. As electronic trading develops, for example, in paperless purchasing, new practices are being adopted, such as assumed receipt (where goods are not automatically counted or checked upon receipt) and use of a delivery or shipping note sent electronically which, with bar coding and assumed receipt, renders an invoice superfluous. Electronic Information Exchange is a later stage of the EDI trading relationship. This is a series of inferences, taken from the supply cycle diagram, which says that, once people are using EDI, they begin to use other electronic network services to gradually replace the more traditional telephone, letter, and personal call. The effect of new technology on the EDI market is estimated to have a positive 1 percent effect on the baseline growth in 1995 to 2000.

The rebirth of the international network services operators as they emerge from the declining time-sharing market and seek to create and exploit new markets is a factor in the growth of EDI services. This also applies to the conventional computer service bureau industry and the operators of the newer videotex/electronic mail services. This is a reborn and revived industry, heavily dependent upon external factors for its growth and maturity—factors that include deregulation, technology, international competition, standards, and local investment and commitment. Business is now global, 7 days a week, 52 weeks a year, 24 hours a day. To survive in the international arena, businesses must ignore time and geographical constraints. Banking deregulation, dealing, brokerage, and commodity trading trends have already proven this point. The ability of companies to electronically reconcile accounts is already causing banks serious concern. The loss of corporate paper handling business may ultimately cause dramatic reductions in banks' branch operations, and precipitate their aggressive entry into the EDI/EFT service provider market. New EDI services will increase the use of EDI as the benefits are easier to realize in industry. Thus this will increase demand by 5 percent from 1992 to 2000.

The factors that affect the growth of EDI are summarized in figure 2-97.

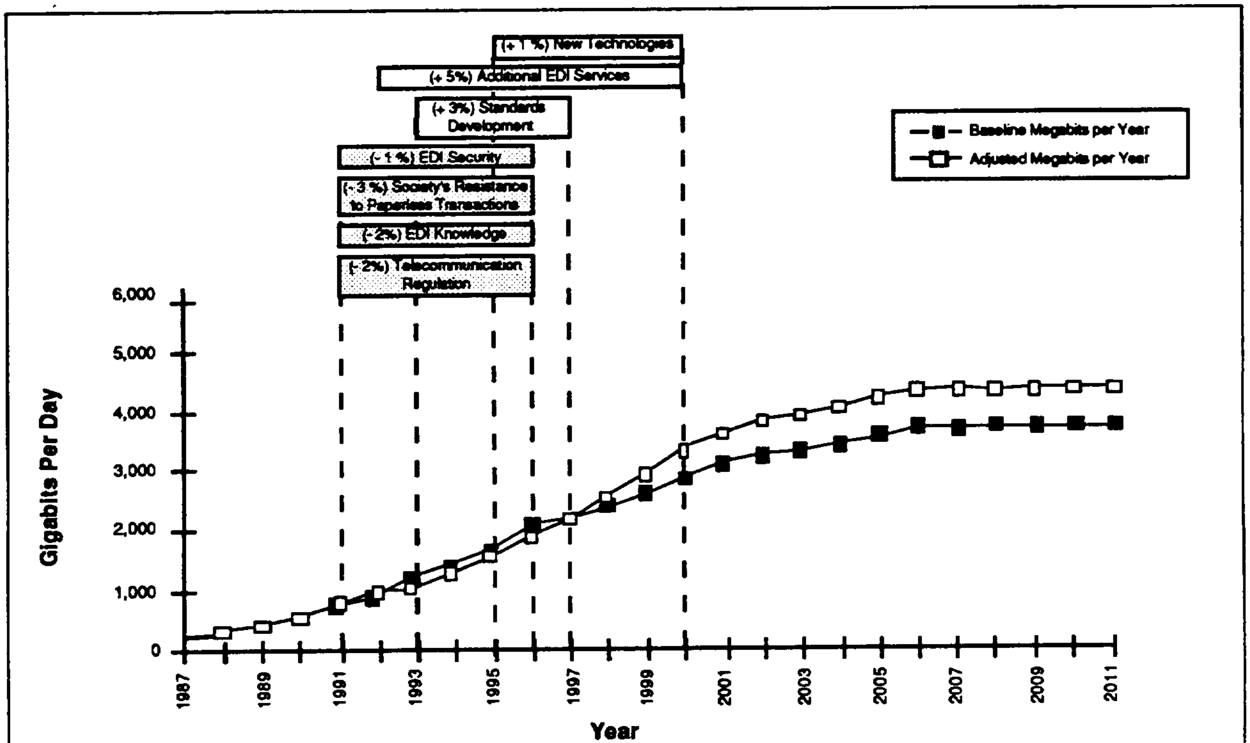
FIGURE 2-97
Summary of EDI Factors

Factor	Effect on EDI Growth	Duration of Effect
Telecommunication Regulation	-2%	1991 - 1996
EDI Knowledge	-2%	1991 - 1996
Security of EDI	-1%	1991 - 1996
Society's Resistance to Paperless Transactions	-3%	1991 - 1996
Development of Standards	+3%	1993 - 1997
New Technologies	+1%	1995 - 2000
Additional EDI Services	+5%	1992 - 2000

Source: Booz·Allen Analysis

By applying external factors to our baseline EDI forecast, an adjusted projection of EDI usage through the year 2011 is developed. These projections are shown in Figures 2-98 and 2-99.

FIGURE 2-98
EDI Adjusted Growth



Source: Booz-Allen Analysis

FIGURE 2-99
EDI Adjusted Projections

Year	EDI Gigabits Per Day	Adjusted EDI Gigabits Per Day
1991	800	800
1996	2100	1950
2001	3200	3800
2006	3700	4400
2011	3800	4500

Source: Booz-Allen Analysis

2.4.10 Research Networks

Research networks include what has commonly been called the Internet: the collection of international computer networks that include research universities, government agencies, and industrial sites (Contel Federal Systems December 1989; Contel Federal Systems December 1990).

The largest backbone among the research networks is National Science Foundation Network (NSFNET), partially supported by the National Science Foundation and currently run by

Advanced Network and Services (ANS) under a subcontract from Merit, Inc. Major components of U.S. research networks include the following networks examined in recent NASA studies:

- NSFNET
- Department of Defense research networks (ARPANET, DRI)
- NASA networks (NSI, NSN, SPAN, NASNET, NASCOM)
- Department of Energy research networks (ESNET, MFENET, HEPNET, LEP3NET, OPMODEL)
- BITNET (Because It's Time NET) and CSNET (Computer + Science NET) (Contel Federal Systems 1989).

NSFNET is the major backbone of the Internet. Estimates of current traffic were obtained from Merit, Inc. and are shown in figure 2-100 (Habegger 1991, 21-26). The breakdown of this traffic is shown in figure 2-101 (Habegger 1991, 21-26); file transfer is the principal use.

In addition to the Internet that is now run by ANS, commercial Internet-like services are being planned by the Commercial Internet Exchange (CIX.) The founding members of CIX include Performance Systems International, UUNET Technologies, and General Atomics. Sprint joined the organization as of January 2, 1992. Sprint estimates that its service, SprintLink, will be available at approximately 300 points of presence, offering a mix of 9.6- to 56-kb/s rates and standard FT1/T1 speeds (Telecommunications February 1992, 9).

FIGURE 2-100
Traffic on the NSFNET/Backbone

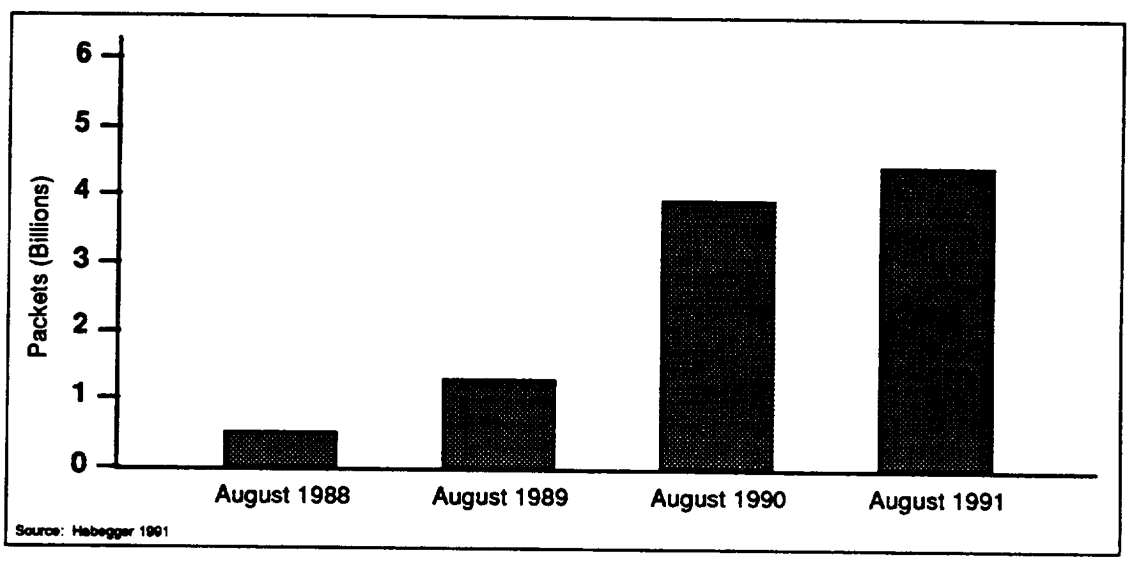
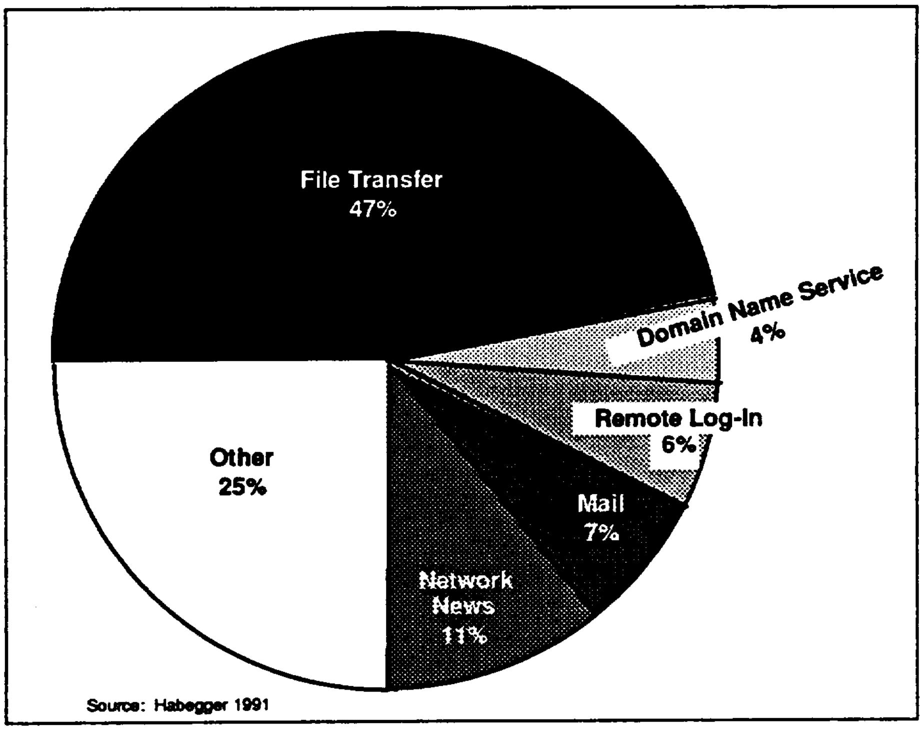


FIGURE 2-101
NSFNET Network Usage as a Percentage of Total Bytes



One of the visions of the future of Internet seen by the EFF is that of a "National Public Network," "a ubiquitous digital web, accessible to every American in practical, economic, and functional terms" (Barlow 1992, 35:25). This network would carry traditional telephone service, e-mail, software, fax, multimedia, as well as HDTV and other future media. It is unlikely that Internet will replace the present PSN as the principal telecommunications medium for the United States. It is more reasonable to interpret this prediction as agreeing with others who have speculated that BISDN may replace today's circuit-switched PSN infrastructure.

The future course of Internet depends on the answers to several questions. Some of these answers will evolve naturally from the application requirements and how these are met in the marketplace. Other answers may be determined by actions of the U.S. government and, to some extent, international organizations. The principal questions are (Contel Federal Systems 1989):

- Who should use the network? Will it be used mainly by research institutions or will it also come into common use by engineering and development organizations or even the general public?

- Who should pay for the network creation and own the network? Should the government make a major direct investment or just sponsor the research into areas such as inter-networking protocols?

- Who should manage the network? If the network develops as part of the PSN, then assumedly the PSN carriers would manage it, much as the PSN is managed today. If it develops largely independently of the PSN, or its development involves new players, such as cable TV operators, then some specific management structure may have to be developed.

- What are the requirements that the network must satisfy? Do very high data rates (many megabits or even gigabits per second) have to be delivered over local loops outside the areas that are economical to wire with optical fiber?

- What transition mechanisms will be needed to reach the desired configuration? What research and development is needed for this? What standards will be needed? What institutional changes may be needed?

- What are the international implications in the areas of national and industrial security, economic competitiveness, and free interchange of ideas?

Today, Internet is already pervasive among major research institutions. The extent of future traffic growth among these institutions is very unclear. Its spread much beyond its current subscribers and current applications would seem to be severely constrained by the increasing availability of high-data-rate circuit-switched and packet-switched services on the PSN. The applications generating the kind of traffic Internet carries are considered in other sections of this report. Therefore, this report does not make any projections for Internet traffic during the study period.

2.4.11 Data Traffic Summary

Figure 2-102 summarizes the traffic projections for the data category.

FIGURE 2-102
Data Traffic Projections Summary

Year	Fax Minutes/ Year (Billion)	E-Mail Terabits/ Day	Terminal Operations Terabits/ Year	On-line Information Services Gigabits/Day	EFT Terabits/Day	EDI Gigabits /Day
1991	28	0.0045	2800	12.5	2.6	800
1996	58	1.60	5100	33	8.1	1950
2001	16.0	88	8100	72	14.0	3800
2006	4.0	440	12,000	170	16.0	4400
2011	5.4	920	17,500	420	16.5	4500

Source: Booz-Allen Analysis

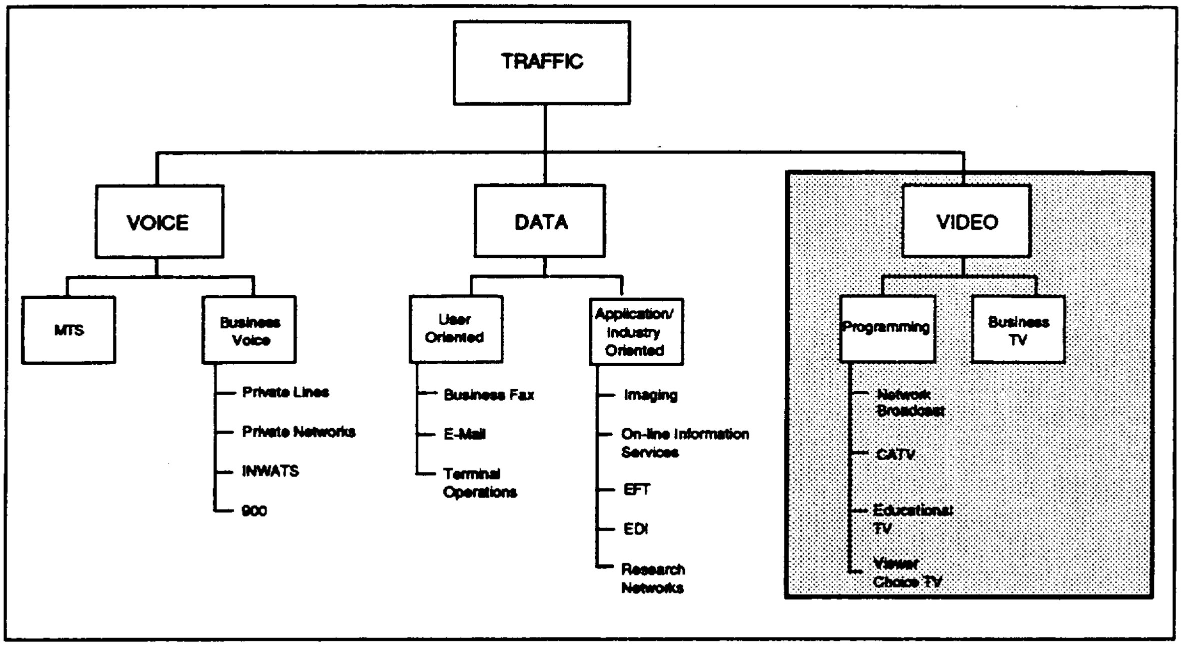
2.5 VIDEO TRAFFIC

The video category has been divided into two types of traffic-generating applications: video programming and business television. Figure 2-103 highlights the video category and shows the segments of demand that make up this category. The video programming category summarizes the telecommunications traffic demand for the commercial broadcasting industry. The business TV category summarizes the telecommunications traffic generated by video transmissions for the private business, government, and institutional sectors.

2.5.1 Video Programming

The video programming category is divided into four distinct categories of demand: network broadcast, cable television, educational television, and video on demand.

FIGURE 2-103
Video Traffic Categories

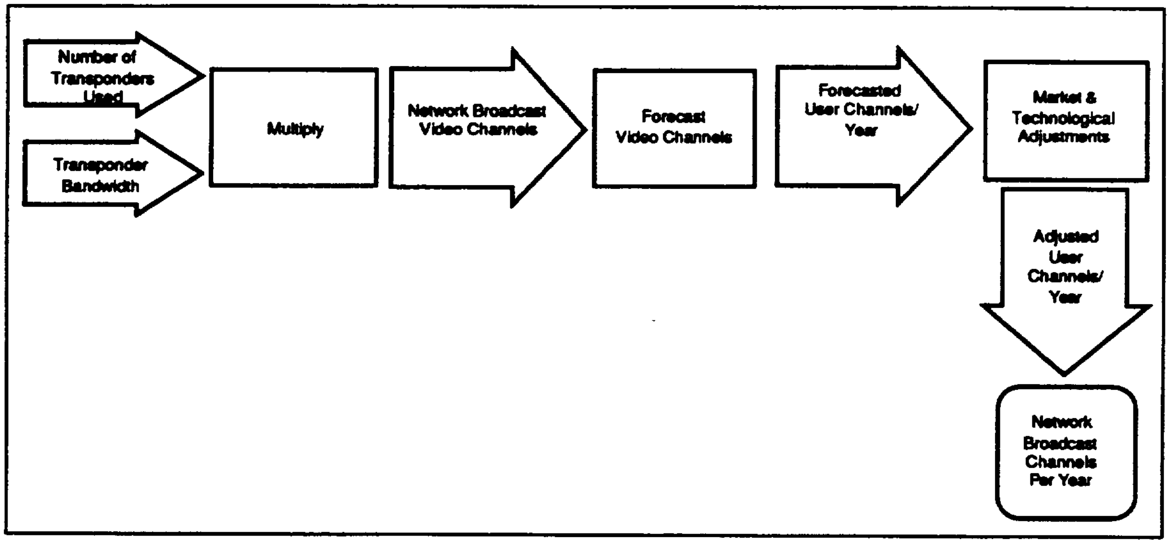


2.5.2 Network Broadcast

The network broadcast category is composed of commercial and noncommercial broadcasting systems that develop and deliver full-time nationwide programming (i.e., ABC, CBS, NBC, Fox, and PBS). Network broadcasts either originate at network headquarters (distribution) or are developed from transmissions from the around the world (collection) (e.g., newscasts and worldwide coverage of events) and transmitted to the network hub. In either case, the programming is processed and transmitted from a network hub to the many affiliates across the United States.

2.5.2.1 Method. The video traffic generated by the major networks is forecasted based upon current demand and planned use of satellite transponders. In the next step of the analysis, the number of network broadcast video channels is derived from the demand for satellite transponders by the major networks. The user channel demand is used to forecast the future demand for network broadcast video channels through the target years. Finally, we adjust our baseline curves to reflect expected market and technological changes that may alter the pattern in the future. The data flow diagram for the network broadcast category is shown in figure 2-104.

FIGURE 2-104
Network Broadcast Data Flow Diagram



2.5.2.2 Baseline Projection. The major networks have agreed on leases with the satellite system operators for transponders through the end of this century. The number of transponders leased by the networks was obtained directly from the networks (Albert F. Caprioglio of Communications System Development, interview). Figure 2-105 summarizes these data. To forecast the future demand for network quality video channels, it is important to determine the planned usage for the transponders by the networks. Transponders are used for both collection and program distribution (i.e., broadcast). The expected use of the transponders was also obtained directly from the networks (Albert F. Caprioglio of Communication Systems Development, interview). These data are summarized in figure 2-106.

FIGURE 2-105
Current Network Transponder Usage

Network	C-Band	Ku-Band	Total Transponders	Total Broadcast Quality Video Channels
ABC	7		7	7
CBS	10		10	10
NBC	1	8	9	9
PBS	4		4	4
Total	22	8	30	30

Source: Albert F. Caprioglio

FIGURE 2-106
Planned Network Transponder Usage

Network	Years	Total Broadcast Quality Video Channels
ABC	1993 - 2005	9
CBS	1992 - 2004	12
NBC	1995 - 2007	9
PBS	1993 - 2005	6
Total		36

Source: Albert F. Caprioglio

Our baseline projections indicate that the networks will increase transponder usage after the launch of new satellites in the early 1990's. The corresponding increase in transponder use is an indication that the networks anticipate the increased capacity will meet the needs of the network through the end of the lifespan of the satellite. The actual use of transponders will increase incrementally during the lifespan of the satellite. However, because those transponders are leased by the networks, it is assumed, for the purpose of this study, that the networks will make full use of all their transponders as soon as they become available.

Because the networks will increase the use of transponders after the launch of satellites, the demand for transponders by network broadcasters will increase in steps during the years new satellites are launched and will maintain the same transponder demand for 12 years (the current life span of satellites). Our initial data from the networks indicate that the demand for transponders will increase from 1992 through 1994, which corresponds to the launching of Galaxy IV, Galaxy VII, Telestar 401, and Telestar 402.

Currently, network broadcasters are using one transponder to transmit a single network quality video channel. Our baseline forecast maintains this assumption and incorporates existing network plans. Based upon this assumption, the demand for network quality video channels is in a direct 1:1 relationship with transponder demand. Therefore, the demand for network quality video channels will increase with the same steps during the years 1992 to 1994.

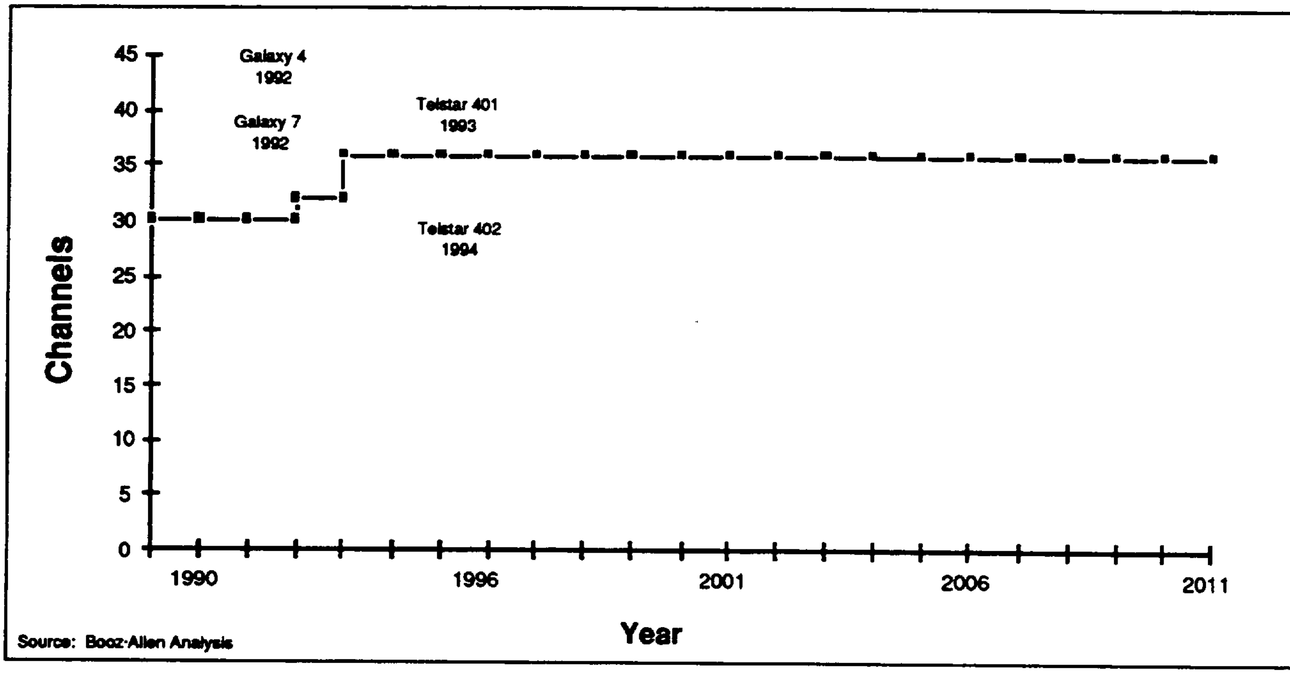
A summary of our baseline projections is shown in figures 2-107 and 2-108.

FIGURE 2-107
Baseline Network Broadcast Projections

Year	Number of Broadcast Quality Video Channels
1991	30
1996	36
2001	36
2006	36
2011	36

Source: Booz-Allen Analysis

FIGURE 2-108
Network Broadcast Baseline Video Channel Growth



2.5.2.3 Adjusted Projection. Network quality video channels were forecasted based upon the networks' expected need for transponders for the next 12 years. These forecasts do not reflect the technological advances that may revolutionize the broadcast industry nor the competition with cable and other programming sources.

A major technological advance that will affect our baseline forecasts will be compression technology. Compression will allow the networks to transmit more than one network quality video channel per transponder, thus allowing the networks to broadcast more channels over their current transponder base. This would allow for regional commercials and programming, or an increase in the diversification of the programming. Current technology forecasts predict a range of 4 to 18 television channels per satellite transponder (EDGEOn & About AT&T, 11 May 1992, 7:7). The high end of this range corresponds to video services like videocassette recorder (VCR)-quality movies, while the low end of this range covers "broadcast quality" transmissions. The network broadcasters will end up at the very low end of this spectrum because of the "network quality" video that is required. We project that the three commercial networks will utilize an additional 3 channels each for these purposes, starting around 2000. The additional channels will be used for regional commercials and, perhaps, some amount of regional programming in addition to time-zone programming. During hours when the network is not distributing programming to affiliates, the additional capacity will be used for additional program collection. Since PBS does not distribute commercials, we assume they will use one additional channel for program collection.

The emergence of the new FCC-approved HDTV standard will be a major factor in the future of network broadcasters. In April 1992, the FCC outlined its 15-year transition plan for a shift from existing TV transmission technology to HDTV (Schiff 14-15 May 1992). According to the FCC plan, only existing broadcasters will be allowed to apply for a HDTV channel. The stations will have 5 years starting in 1993 to apply for a HDTV license. Once the license is granted, the broadcasters then have four years to program the HDTV station to duplicate its regular TV station. By 2008, the stations will have to end their standard transmissions and broadcast only HDTV signals (David, 10 April 1992, B1). To view HDTV, the consumer will have to buy new HDTV television sets.

The advent of HDTV will require the networks to address many issues relating to the distribution of network programming. For example, what infrastructure will the networks use to carry HDTV signals and when will they start using it? These plans have not yet been made. For the purposes of this report, we assume that the networks will, at some point, switch over very quickly to distributing only HDTV to their affiliates. The affiliates will broadcast this signal on their HDTV channel and will convert it to the present format for broadcast on their existing channel. Thus, we assume that HDTV causes no change in the number of TV channels used by network broadcasters. The effect of HDTV's high bit rate is considered later as part of the process of converting user channels to the common denominator of DS0s.

"Viewer choice" TV will be a competitive force that may impact the networks. Viewer choice TV describes a service much like an interactive on-screen TV guide, which allows the viewer to dynamically choose individual channels or even individual programs to be transmitted or shown on the viewer's television set. Examples of this technology are being tested and implemented by both the service providers and the television manufacturers. For example, AT&T is working with US West and Tele-Communications Inc. to explore enhanced pay-per-view and video-on-demand service in a market trial set for the summer of 1992 in Denver (EDGEOn & About AT&T, 11 May 1992, 7:7). In addition, Zenith Electronics Corp. and InSight Telecast Inc. are working on a joint development deal to offer televisions equipped with a decoder device that displays real-time TV listings and allows selection of programming via on-screen menus (Mallory, 30 April 1992).

Viewer-choice TV will be offered by cable systems. While the networks will feel the effect of this increased competition, there is nothing obvious they can do to respond. Therefore, we project no increase in network broadcast transmission usage in response to viewer-choice TV. On the other hand, even if their market erodes even further due to the competition, decreasing their transmission would not be a reasonable cost-saving measure. Therefore, we project no net change due to viewer-choice TV.

Another element that may affect the demand for network quality video channels is the expanded use of fiber optics for program contribution and distribution. As stated, "Nightline" on ABC is an example of the current uses of fiber cable to contribute to programming. Furthermore, the networks are considering using fiber for point-to-point program distribution. The bandwidth capacity and near flawless transmission of fiber optics at potentially lower costs would allow the networks to increase their use of video channels for an incrementally smaller economic investment. Any increase in transmission usage due to this is speculative, and is intended to be included in the additional channels assumed above in connection with compression technology.

The advent of DBS can only have a negative effect on the network broadcasters' business. As for viewer-choice TV, we feel that there is no response the networks can make that will affect, positively or negatively, the number of transmission channels they use. The overall effect of these changes in the network broadcasters' business environment is shown in figure 2-109.

FIGURE 2-109
Adjusted Network Broadcast Projections

Year	Forecasted Network Broadcast Video Channels	Adjusted Network Broadcast Video Channels
1991	30	30
1996	36	36
2001	36	46
2006	42	46
2011	42	46

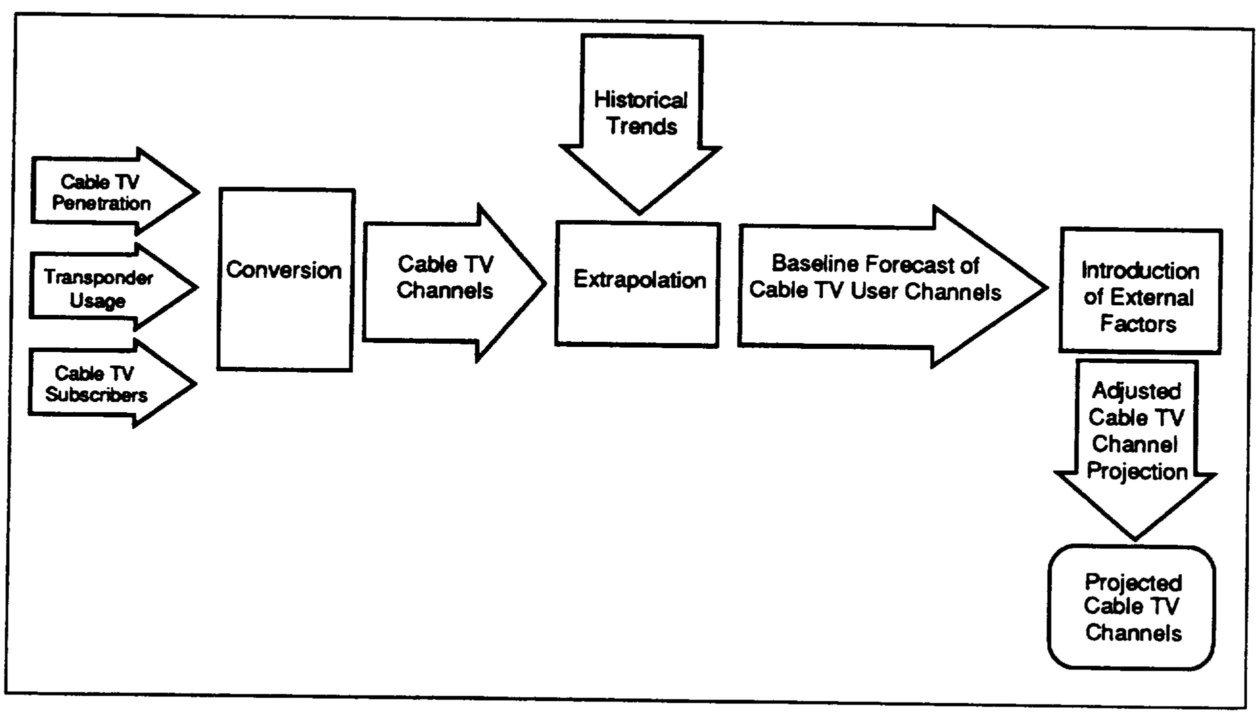
Source: Booz-Allen Analysis

2.5.3 Cable Television

Cable TV comprises programming originators, other than networks, broadcasting their programs on a regional or national basis, full- or part-time. Cable TV distribution relies on satellite transmission (national and regional) as well as 75-ohm coaxial cable (local). The cable TV industry is characterized by national, regional, and local program providers and locally franchised distributors.

2.5.3.1 Method. The future cable TV demand is assessed by identifying historical trends of key demand drivers and developing an integrated demand forecast. Our forecast is influenced by capacity constraints, new technology infusions, market developments, and industry cost structures. Figure 2-110 shows the data flow diagram for cable TV traffic projection.

FIGURE 2-110
Cable TV Data Flow Diagram



2.5.3.2 Baseline Projection. The cable TV market has matured. Subscriber growth and penetration levels will show modest growth over the study period. Program channel increases will continue to show strong growth, due to a rise in niche programming, and provide the major impetus for cable TV expansion. These trends are demonstrated in the graphs in figures 2-111 and 2-112 (International Communications Research).

FIGURE 2-111
Cable TV Homes Passed

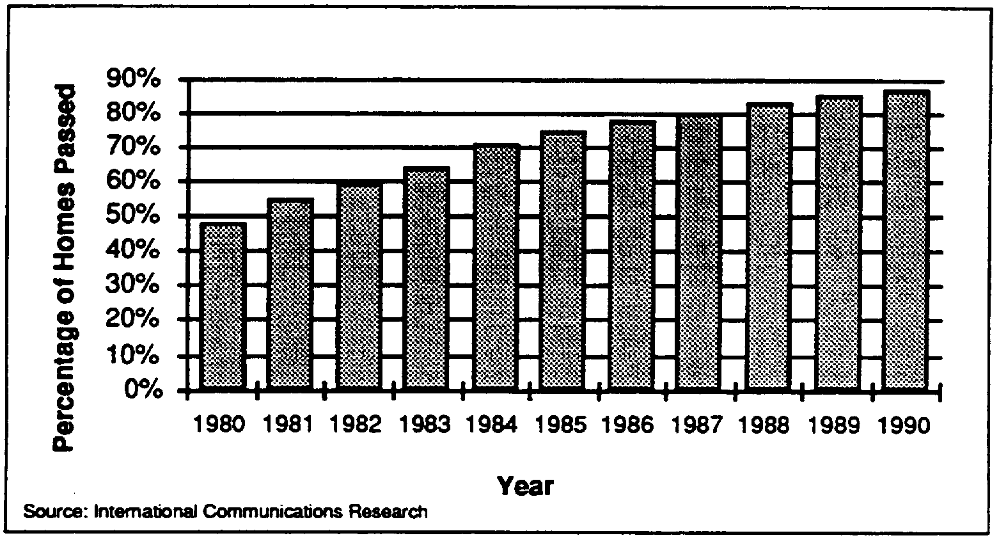
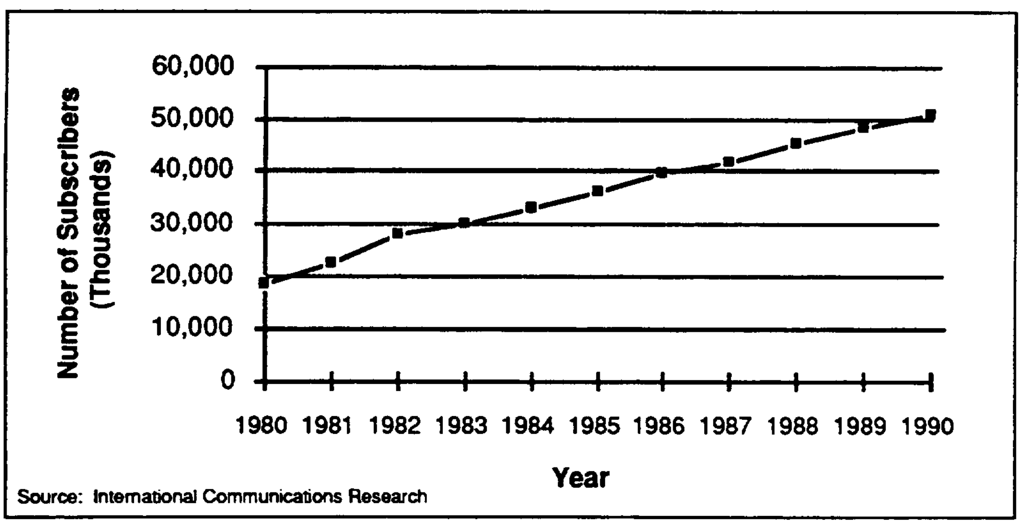
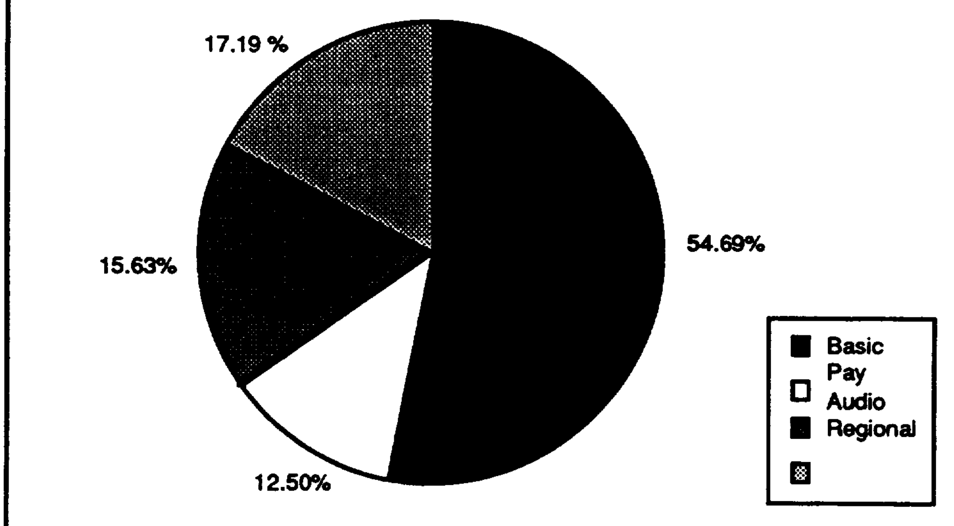


FIGURE 2-112
Cable TV Subscribers



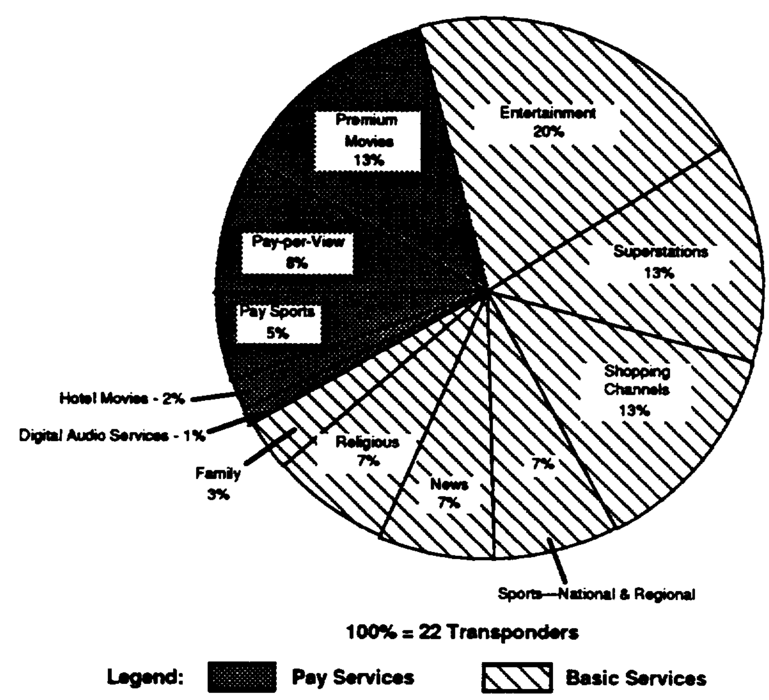
Collectively, the demand drivers indicate that programmers will attempt to increase revenues in a stable market by diversifying channel offerings and targeting smaller, more specific audiences. Thus, while the overall cable TV market as measured by subscriber count will stabilize, demand for user channels will remain strong. Figures 2-113 and 2-114 shown additional trends in the cable market (Official Westsat Satellite Comm Chart Jan/Feb 1989, The Television Factbook 1988).

FIGURE 2-113
Cable TV 1985 Market Share



Sources: Official Westsat Satellite Comm Chart Jan/Feb 1989
The Television Factbook 1988

FIGURE 2-114
1989 C-Band Transponder Demand



Sources: Official Westsat Satellite Comm Chart Jan/Feb 1989
The Television Factbook 1988

Historical data for the use of cable TV transponders are shown in figure 2-115 (National Cable TV Assoc, telephone conversation, 4 January 1992). Currently, one dedicated cable TV transponder equals one cable TV user channel. Compression technology will allow multiple programming channels to be transmitted through a single transponder. Therefore, our analysis defines a cable TV user channel as a programming channel. For example, HBO currently transmits two signals, east and west, amounting to two user channels.

FIGURE 2-115
Historical Trends in Cable TV Transponders

Year	Total Cable TV Transponders
1984	63
1985	66
1986	80
1987	97
1988	107
1989	116
1990	129
1991	140

Source: National Cable TV Associates

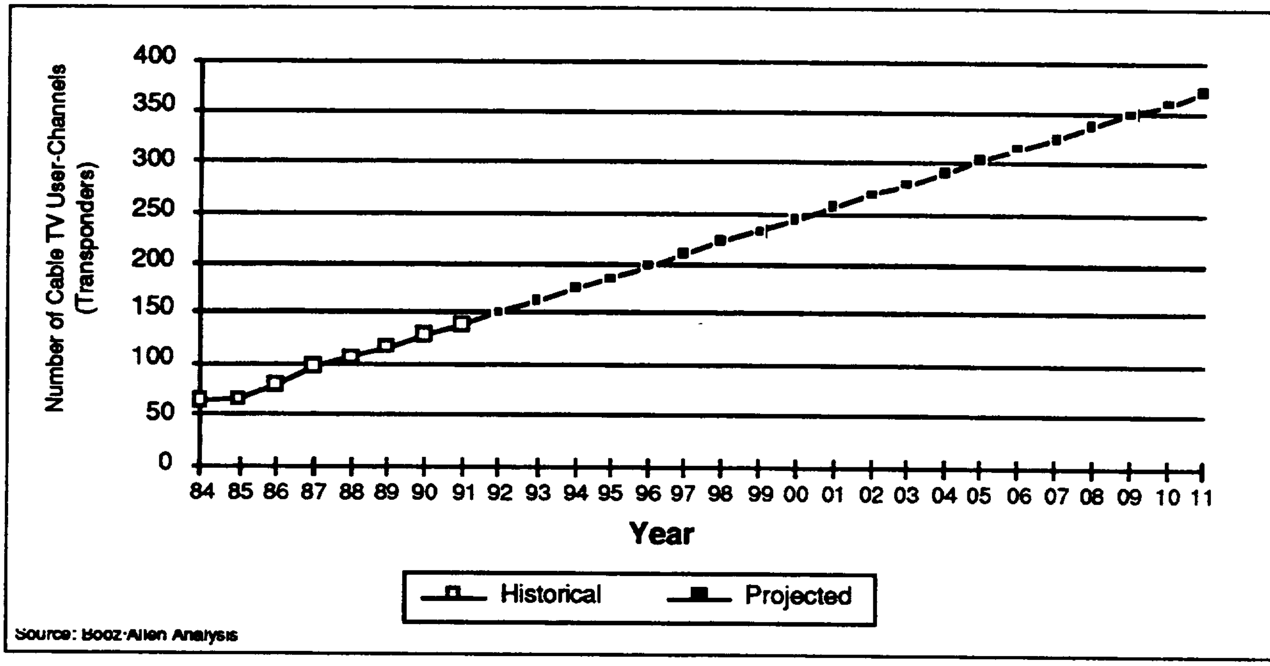
Based on historical channel growth, a linear growth pattern is used to project cable TV channels through the year 2011. The growth obtained by extrapolating this base data is shown in figure 2-116 and summarized in figure 2-117. Driven primarily by regionally oriented 'niche programming' growth, our baseline forecast indicates 372 user channels will be required by the year 2011.

FIGURE 2-116
Baseline Projection of Cable TV Channels

Year	Number of Cable TV User Channels
1991	140
1996	198
2001	256
2006	314
2011	372

Source: Booz·Allen Analysis

FIGURE 2-117
Cable TV Video Channel Baseline Projection



2.5.3.3 Adjusted Projection. External factors will have an extensive influence on the growth rate of cable TV user channels. These factors are summarized in figure 2-118.

FIGURE 2-118

Factor	Effect on Baseline Projection	Duration of Effect
Compression Technology	+2%	1996-2006
Niche Programming	+1%	1992-2006
Subscription Charges	-1%	1991-1994
Competition from LECs	+1%	1996-2006
Antenna Cleared Area	-1%	1991-1996

Source: Booz-Allen Analysis

Compression technology will have a significant effect on the future growth of cable TV channels. As discussed in section 2.5.2.4, current projections of video compression ratios range from 4 to 18 channels per transponder. Even though these estimates show the potential to greatly increase cable channels, it is more likely that a gradual increase will result from the actual compression technology development because the market is constrained by the cost of providing the programming to spur the growth. More likely, other factors will provide the impetus to use the expanded transmission capacity created by compression technology. This reasoning is reflected in percentage increases estimated for the other factors that affect cable channel growth. A 2 percent increase per year is estimated for cable channel growth due to compression technology in the 1996 through 2006 time frame.

The push for both regional and niche market programming is a factor that will spur cable channel growth. The popularity of specialized programming like shopping channels, religious programming, and comedy channels may pave the way for the introduction of even more niche market-oriented programming (Baron, 16 December 1991, 7:5-9) As compression technology gives the local cable affiliate more channel space, these services become more cost effective and feasible. This factor is used to increase the baseline projection by 1 percent from 1992 through 2006.

The issue of increasing subscription charges is one of two negative factors that we use to modify the baseline projections. As more channels are being added by the local cable franchises, they are also raising basic and premium channel subscription rates. In the absence of local competition, many cable franchises have been accused of overcharging their subscribers (Baron, 16 December 1991, 7:5-9) These facts have caused people to weigh the cost of pay TV against 'free' TV. We see these factors contributing a 1 percent decrease in cable channel growth in the 1991 to 1994 time frame until subscription charges stabilize at customer-acceptable rates.

Competition from the LECs in the cable arena is seen as a factor contributing to growth in the demand for cable channels (Mason, 10 February 1992, 222:11-12). As the telephone companies are allowed into the video distribution business, they offer another means of delivering cable programming to the consumer (Andrews, 19 August 1991, 140:C3(N)). This factor is seen as a 1 percent contributor to cable channel growth in 1996 through 2006.

Another factor that constrains the cable channel demand growth rate is the number of antennas used by the local cable franchises to receive programming. The C-band antennas that are used require a cleared area for clear reception of satellite signals and for frequency interference restrictions. For many franchises, these restrictions have prevented them from obtaining new satellite antennas to receive signals from more than their current cable satellites. The addition of new cable channels on new satellites does not provide new programming opportunities for these franchises because they cannot install new antennas to receive the satellite transmissions. This factor is estimated to have a -1 percent effect on cable channel growth in the 1991 to 1996 time frame.

By applying external factors to our baseline cable forecast, an adjusted projection of video channels through the year 2011 is developed. These projections are shown in figures 2-119 and 2-120.

Figure 2-119
Cable TV Video Channel Adjusted Growth

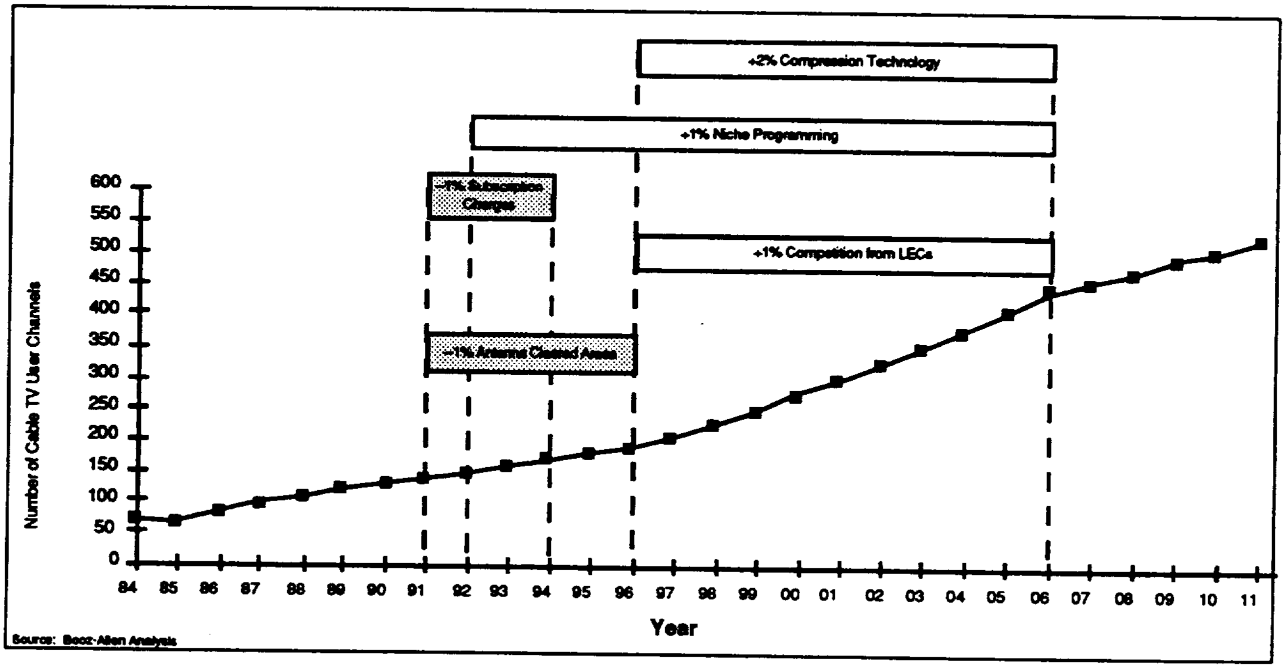


FIGURE 2-120
Adjusted Cable TV Forecast

Year	Number of Cable TV User Channels (Baseline)	Number of Cable TV User Channels (Adjusted)
1991	140	140
1996	198	195
2001	256	300
2006	314	440
2011	372	520

Source: Booz-Allen Analysis

2.5.4 Educational Television

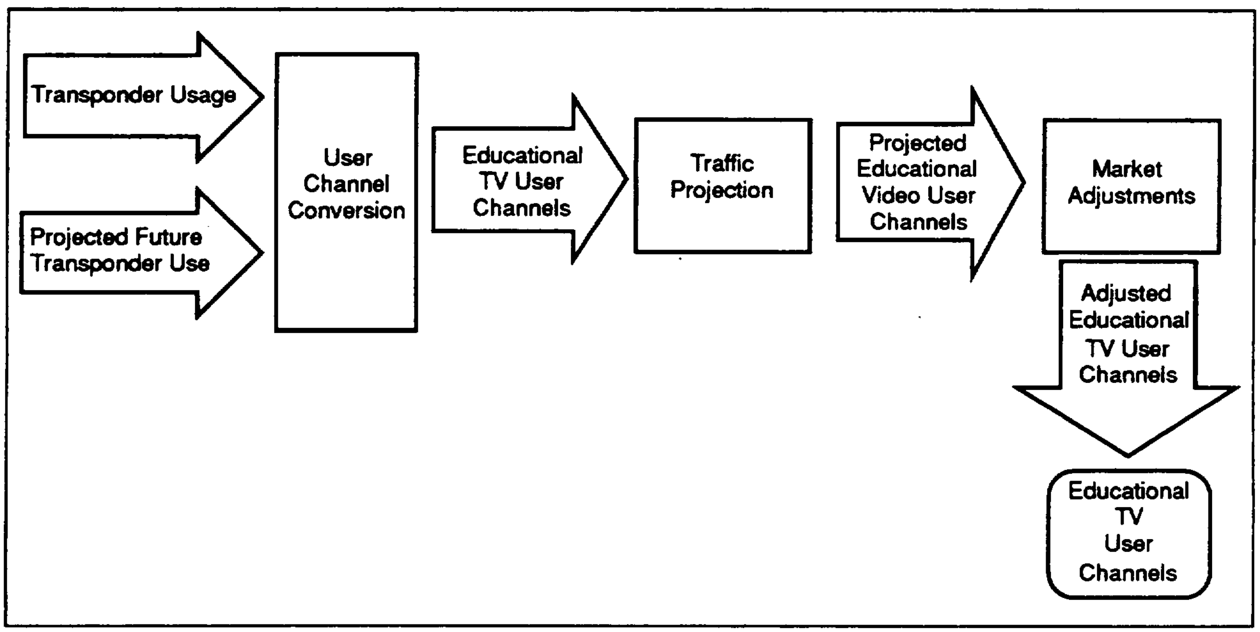
Educational television has the potential to revolutionize the American educational system. Educational television comprises one-way point to multipoint video that provides classroom instruction to large audiences in schools and universities. The benefits from video telecommunications are now being realized by educational institutions. Through educational video, both urban and remote rural schools gain equal access to more educational material. Additionally, educational video transmission can be used to provide equal access to highly specialized teachers (e.g., Russian and Japanese instructors) and sources of education.

However, there are still many economic, political, and social problems associated with the use of video telecommunications in the U.S. educational system. For example, the cost of video television equipment and occasional-use transponders are prohibitively high, there is no governing body to organize and coordinate the educational television movement, and there are still many doubts about the viability of educational television in today's schools.

Educational television has the potential to grow substantially over the next decade. If certain conditions are achieved, educational television could be an explosive market. However, the video telecommunications market is still relatively new and it will be some time before society is prepared to fully accept these technological advances.

2.5.4.1 Method. The video traffic generated by educational television, measured in equivalent video channels is forecasted based upon its current use of satellite transponders. The future user channels for educational television are then projected from current usage statistics and industry expert insight into the growth rate of this market. Finally, we adjust our curves to reflect expected market and technological advances that may alter the current pattern in the future. The data flow diagram is shown in figure 2-121.

FIGURE 2-121
TV Data Flow Diagram



2.5.4.2 Baseline Projection. Educational video baseline forecasts are based on the current demand for educational television programming. Our initial data indicated that the educational television market currently consists of the following (the EDSAT Institute 1991):

- Nine C-band and 8 Ku-band satellites with 30 and 22 full or occasional-use transponders for educational services respectively
- One hundred and eleven educational programming providers
- The 20 largest program providers use 75,000 hours of transponder time (approximately 35 transponders)
- The remaining 91 program providers effectively increase the demand to 45 transponders.

Based upon inputs from industry experts, we project that educational video traffic will increase by 50 percent over the first 10 years and will slow in the next decade. Figure 2-122 shows the baseline projections.

FIGURE 2-122
Baseline Educational TV Forecast

Year	Educational TV Transponder Usage	Number of Educational TV User Channels
1991	48	48
1996	59	59
2001	72	72
2006	80	80
2011	90	90

Source: Booz-Allen Analysis

2.5.4.3 Adjusted Projection. Because the educational television market is in the early stages of development, the adjusted forecast supplements the baseline forecast with important external market and technology factors.

There will be many factors that can greatly reduce or increase the future demand for educational video channels. For example, if educational video distribution is adopted as the standard approach for the entire U.S. educational system, the demand for educational video channels will grow at exponential rates over the next 20 years. However, educational video may also become enmeshed in economical, political, and social concerns that could decrease the current demand for educational video channels.

Our adjustments to the baseline forecasts are provided to offer reasonable expectations of the future demand for education video channels. There are many external factors that cannot be fully evaluated at such an early stage of the marketing cycle.

A factor that has limited the growth of educational television has been the lack of a national education organization. A national organization could coordinate the purchase of transponder time to gain the maximum economic benefit from the investments. The organization would provide a single contact that would increase institutions' capability to obtain transponder time at a reasonable cost. Because of the lack of an organized movement, we adjust our baseline projections downward by 1 percent in 1991 to 1997.

Compression technology will be another major factor for educational institution demand for video channels. Compression technology would decrease the cost of video channels because transponders could transmit more than one video channel simultaneously and would increase the supply of occasional use transponders. Compression technology will have a significant impact on the demand for educational video channels; a 3 percent increase is projected in the 1995 to 2005 time frame.

In recent years, costs of technology have decreased substantially. Video conferencing rooms that once cost over $100,000 can now be set up for less than $25,000. This cost reduction has allowed more educational institutions to get involved with educational television. The lower costs have an effect on the growth of educational TV. We estimate a 1 percent increase in growth in the 1993 to 2000 time frame.

The greatest effect on the demand for educational video channels will be the integration of video TV into the educational system. This has been one of the major reasons for the slow growth of educational video demand over the past decade. Once educators realize the importance and value educational TV can have on the U.S. educational system, the demand for video channels could grow rapidly. We estimate a 2 percent increase in growth in the 2001 to 2011 time frame.

The factors that have been discussed in this section are summarized in figure 2-123. These factors are used to adjust the baseline projection of educational TV video channels. Figure 2-124 shows the adjusted projections.

FIGURE 2-123
Summary of Educational TV Factors

Factor	Effect on Baseline Projections	Duration of Effect
Availability of Cost-Effective Satellite Channels	- 1 %	1991 - 1997
Improvements in Compression Technology	+ 3 %	1995 - 2005
Lower Costs for Technology	+ 1 %	1993 - 2000
Integration of Video Television into Education	+ 2 %	2001 - 2011

Source: Booz-Allen Analysis

FIGURE 2-124
Adjusted Educational TV Forecast

Year	Forecasted Educational Video User Channel Demand	Adjusted Educational Video User Channel Demand
1991	48	48
1996	59	60
2001	72	87
2006	80	120
2011	90	150

Source: Booz-Allen Analysis

2.5.5 Viewer Choice TV

Viewer Choice TV, as discussed in section 2.5.2, is potentially a major factor in the future of entertainment television. By the turn of the century, viewer choice TV will emerge as a source of demand in its own right. This growth will result from the entrance of LECs into the video market with video dial-tone services.

Currently, market and technology tests are being carried out by GTE in Cerritos, CA (Broitman and Kennedy 14-15 May 1992). Technology testing is being performed on VOD services using GTE video switches. Market testing is being performed with Near VOD (NVOD) services to develop a business model of the major research issues including optimum number of channels, programming mix, pricing, promotions, understanding why people do or do not subscribe, and comparing NVOD with VOD.

Another residential TV venture, Viewer-Controlled Cable Television (VCTV), is being offered by TCI, AT&T, and US West. VCTV, currently in the market-trial stages, offers both VOD and NVOD services to the home.

According to Northern Telecom's John Boyd (Boyd, 14-15 May 1992), the LECs see a potential for millions of residential video subscribers by the year 2000. Video dialtone trials are ongoing and volume deployment is expected by 1994.

For the purpose of this report, the interest in viewer-choice TV is from the point of view of the long-distance traffic generated. We assume that VOD services will mainly be provided by a local supplier, possibly the LEC. We assume that most of the programming material will be stored locally, on some kind of "optical jukebox." For material that is requested rarely, there will be national or regional suppliers who can transmit the program material to the local supplier and then to the requesting household, and it is only this material that generates significant long-distance traffic. For this analysis, we assume one such special program, lasting 2 hours, is requested by each subscribing household per month.

We assume that VOD service including long-distance transmission will not be available until 2001. Absent any realistic projections, we assume that, in 2011, half of the number of today's U.S. households will be subscribers. This number is about 93 million, according to the *Statistical Abstract of the United States* (U.S. Bureau of the Census 1990, 45). Expecting that VOD on a local basis will already be established by 2001, we assume 10 million subscribers in 2001, growing to 20 million in 2006 and 46 million in 2011.

Using these assumptions, our projection for long-distance transmission is shown in figure 2-125.

FIGURE 2-125
Long-Distance VOD Usage

Year	Seconds/Year (10^{12})
1991	0
1996	0
2001	0.86
2006	1.70
2011	4.0

Source: Booz-Allen Analysis

This assumed scenario does not consider the cost of this long-distance transmission. At today's off-peak long-distance rates on the order of 10¢ per minute, a 2-hour call costs $12. In section 2.63, we assume that Asymmetric Digital Subscriber Line (ADSL) technology will be used for this transmission at a rate of 2.8 Mb/s, which is the equivalent of 44 DS0s. Thus, a subscriber would be paying $12 x 44 = $528 just for the transmission. Clearly, there is no viable long-distance transmission-to-the-home component to the VOD business until transmission rates for bulk service come down by a factor of 100. An eventual migration of the PSN to BISDN would provide only a factor of 2, since only one direction of transmission is needed, but it is needed full-time for the duration of the program.

2.5.6 Business Television

Business TV is defined as two-way and one-way real-time, video communications (point-to-point, point-to-multipoint, or multipoint-to-multipoint). Business TV is in the initial stages of the market development life cycle. Businesses are increasingly aware of the existing and potential benefits. Business TV provides the ability to reach large audiences with 'live communications' that saves time and money.

Corporations are finding an increasing number of applications for business TV—introduction of new products, training, and management broadcasts to employees. Videoconferencing is becoming an accepted business practice.

Technological advances for business TV have also been major factors in its use and acceptance in corporate society. Transmission costs for a typical videoconferencing system have decreased from $250,000 to $25,000 (Booz·Allen & Hamilton). A VSAT network can be upgraded for business TV for around $2000 per terminal (Compression Labs). Compression technology allows a videoconference to occur over dual 56 kb/s lines.

While there have been great advances over the past few years, large obstacles still remain. The integration of video applications into society is still a long way off. The cost of transmission and setup have to be reduced even further. Finally, videoconferences must become easy to establish over the PSN. When these conditions are met, videoconferencing has the potential to revolutionize U.S. telecommunications. Until then, it will remain a future technology with spectacular potential.

2.5.6.1 Method. Business TV traffic is projected based on codec installations because all video telecommunications traffic including video conferencing and other business TV applications use codecs as a part of the system. Business TV is divided into three segments based on picture quality. Historical data on the installed base of codecs for each segment and codec market trends are used to extrapolate the growth of codecs in the marketplace. The growth of business TV channels is adjusted for external factors to give a final projection of video channels demanded by business TV applications. Figure 2-126 shows the data flow diagram for business TV projections.

2.5.6.2 Baseline Projection. Our analysis of the codec installed base divides the market into three primary areas: limited motion video, limited-full motion video, and full motion video. Limited motion video is currently transmitted at 56 to 384 kb/s and is used for lower-quality video transmission. Limited-full motion video is currently transmitted at 384 kb/s-2.084 Mb/s and is used for lower- to cable-quality video transmission. Full-motion video is transmitted at 45 Mb/s and is approximately equivalent to network quality video broadcasts. Data showing the installed base of codecs from 1985 to 1989 are given in figure 2-127 (Dataquest).

The three business TV categories are used to establish a baseline demand for three classes of video service irrespective of the bit rates or compression factors that are used to transmit the video. These classes of service define the video quality needed by a user community and are therefore the correct measure of demand for business TV channels. The demand for business TV is measured and projected in conference-hours through 2011. These can then be converted into network capacity demanded by estimating the level of compression that will be used for each category over the course of the study.

FIGURE 2-126
Business TV Data Flow Diagram

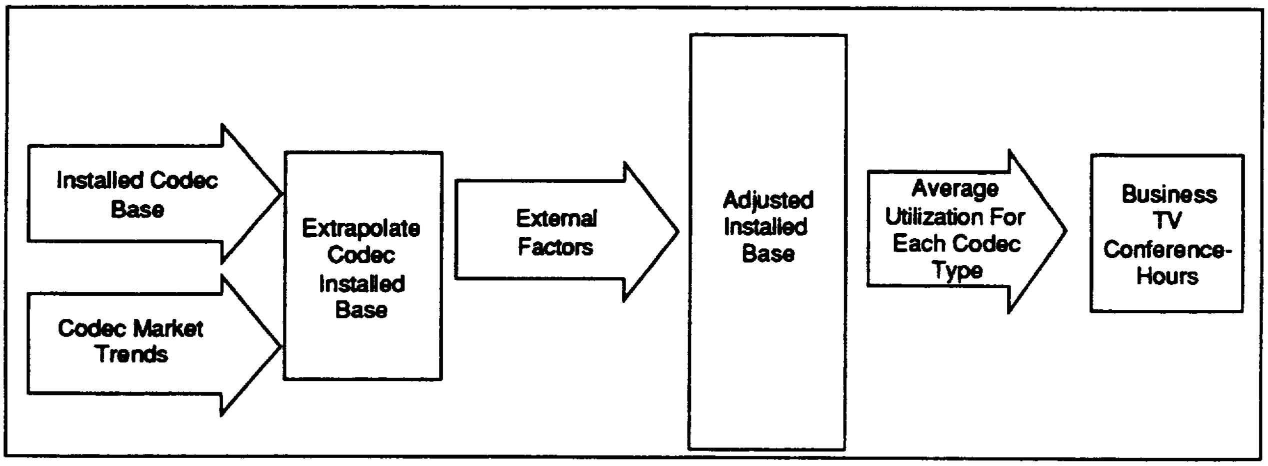


FIGURE 2-127
Codec Installed Base (1985 to 1989)

Year	Limited Motion Video	Limited Full Motion Video	Full Motion Video	U.S. Total
1985	60	360	88	508
1986	70	604	162	836
1987	156	790	372	1318
1988	392	1077	784	2253
1989	1476	1534	1284	4294

Source: Dataquest

Figure 2-128 shows the growth of the three business TV categories. The installed base of codecs has shown substantial growth in the past 2 years, especially in the limited motion (56 to 384 kb/s codec) video conferencing market. This growth is driven primarily by lower transmission and equipment costs, and dramatic improvements in compression technology.

The three business TV categories are fit to s-curves to model the growth of these technology and market-driven applications. These curves and the total projection curve are shown in figure 2-129. The asymptotes of the s-curves are estimated based on the underlying growth of the market segment being measured and the predicted future growth of each category. Initially, limited motion video will have a high growth rate, but will be overtaken by limited full motion video technology in the next century.

2.5.6.3 Adjusted Projection. The growth of business TV user channels is affected by market and technology factors. These external factors affect the baseline projections and give an adjusted projection of the growth of business TV user channels for the study period 1991 to 2011.

FIGURE 2-128
Codec Installation Growth (1985-1989)

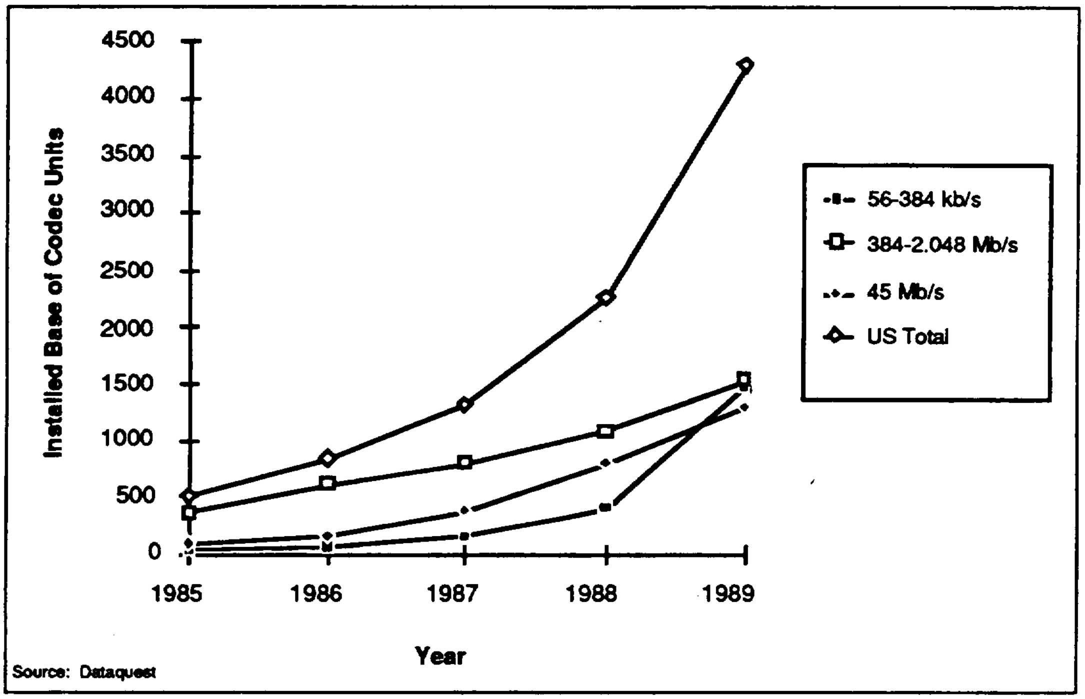
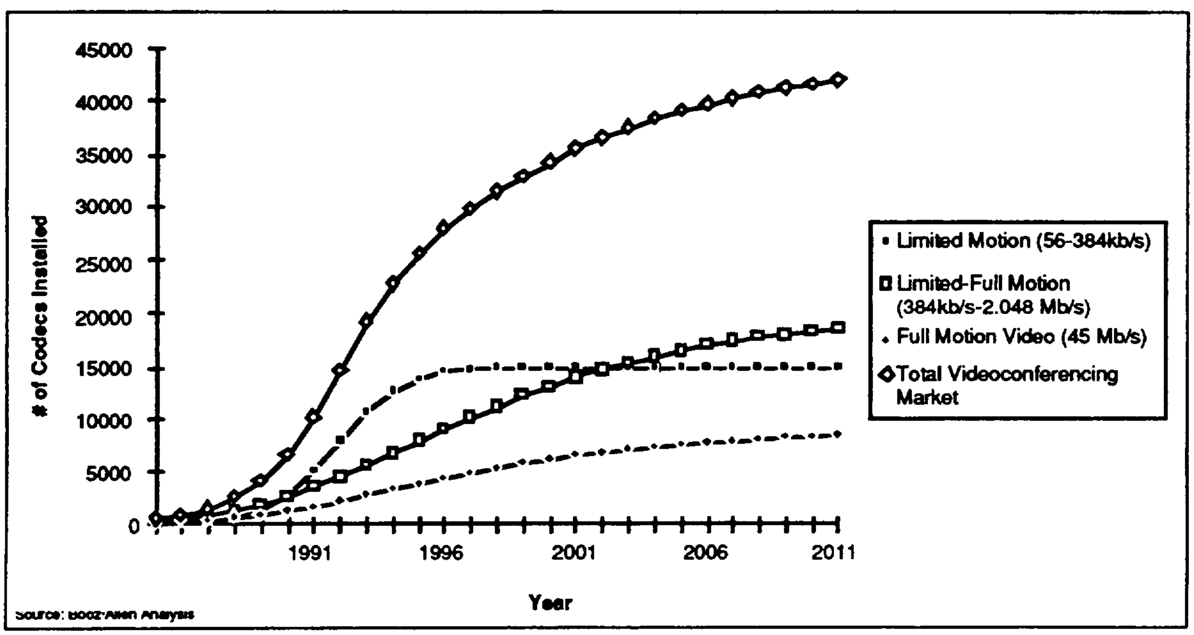


FIGURE 2-129
Baseline Codec Growth



There are four external market and technology factors that will affect business TV growth. These are shown in figure 2-130 and are used to adjust the baseline predictions. The adjustment is made by inferring from the data on installed bases of the three kinds of codecs what the annual shipments must have been in each year. For this process, it was assumed that shipments included new installations plus replacement of 10 percent of the installed base each year. For the years 1994 through 1997, instead of the 10 percent replacement assumption we assumed that in each year 25 percent of the installed base at the end of 1993 was replaced by customers taking advantage of the reduced transmission rates allowed by more efficient compression algorithms. The factors shown in figure 2-130 were then applied to the adjusted annual shipments and new installed bases were calculated for each type of codec. The baseline and adjusted projections for the installed base of each type of codec are shown in figure 2-131.

FIGURE 2-130
Summary of Business TV Factors

Factor	Effect on Baseline Projections	Duration of Effect
Reduction of Compression Technology Market Effects (Compression Labs)	- 1 %	2000 - 2011
Reduced Effects of Equipment and Installation Costs (Compression Labs)	- 1 %	2005 - 2011
Development of Codec Standards (Data Communications November 1991)	+ 1 %	1992 - 2000
Integration of Business TV into Daily Business Activities	+ 2 %	2000 - 2001

Source: Booz-Allen Analysis

FIGURE 2-131
Projections of Business TV Codec Installed Base

Year	Limited Motion		Limited-Full Motion		Full Motion	
	Baseline	Adjusted	Baseline	Adjusted	Baseline	Adjusted
1991	5.0	5.0	3.5	3.5	1.70	1.7
1996	14.5	14.5	9.0	9.1	4.3	4.3
2001	15.0	15.0	14.0	14.0	6.5	6.6
2006	15.0	15.0	17.0	17.0	7.8	7.8
2011	15.0	15.0	18.0	17.5	8.4	8.3

Source: Booz-Allen Analysis

For each of the three codec types, estimates were made of the typical amount of time per business day that video traffic is transmitted. These estimates are five hours per day for limited-motion video and three hours per day for limited-full motion and full-motion video. These are then used to convert the number of codecs into business TV conference-hours. The result of this analysis is shown in figure 2-132.

FIGURE 2-132
Adjusted Business TV Forecast
(Conference-Hours/Day [10^3])

Year	Limited Motion	Limited-Full Motion	Full Motion	Total
1991	25	10.5	5.1	41
1996	73	27	13.0	115
2001	75	42	20	135
2006	75	51	23	150
2011	75	53	25	155

Source: Booz-Allen Analysis

2.5.7 Video Traffic Summary

Figure 2-133 summarizes the video traffic projections.

FIGURE 2-133
Video Traffic Projections

Year	Network Broadcast Video Channels	Cable TV Video Channels	Educational TV Video Channels	Business TV Video Channels (Conference-Hours/Day)	Viewer Choice TV (10^{12} Sec/Year)
1991	30	140	48	41,000	0
1996	36	195	60	115,000	0
2001	46	300	87	135,000	0.86
2006	46	440	120	150,000	1.70
2011	46	520	150	155,000	4.0

Source: Booz-Allen Analysis

2.6 TRAFFIC SUMMARY

This section summarizes the projections for voice, data, and video traffic. Section 2.6.1 summarizes the traffic projections in units suited to the individual demand category. Section 2.6.2 summarizes the busy hour analysis that we performed in order to gauge the relative intensities of the traffic categories in the busy hour of the day. Section 2.6.3 summarizes the traffic projections in equivalent DS0s.

2.6.1 Summary of Traffic Projections

Figure 2-134 summarizes our adjusted traffic projections.

FIGURE 2-134
Traffic Projection Summary

DSOs	Units	Traffic Projections 1991	1996	2001	2006	2011
Voice						
MTS	Call-seconds Per Year (10^{12})	23	30	40	59	87
Private Lines	Voice Channels (10^{6})	1.30	1.80	2.1	1.70	1.40
800	Call-seconds Per Year (10^{12})	2.6	3.9	5.6	7.5	10.0
900	Call-seconds Per Year (10^{12})	0.047	0.081	0.120	0.155	0.190
Private Networks	Call-seconds Per Year (10^{12})	0.72	0.72	0.99	2.0	2.9
Data						
Facsimile	Seconds Per Year (10^{12})	1.70	3.5	0.96	0.24	0.32
E-Mail	Terabits Per Day	0.0045	1.60	88	440	920
Terminal Operations	Terabits Per Year	2800	5100	8100	12000	17,500
On-Line Info. Services	Gigabits Per Day	12.5	33	72	170	420
EFT	Terabits Per Day	2.6	8.1	14.0	16.0	16.5
EDI	Terabits Per Day	0.80	1.95	3.8	4.4	4.5
Video						
Network Broadcast	Video Channels	30	36	46	46	46
Cable TV	Video Channels	140	195	300	440	520
Education TV	Video Channels	48	60	87	120	150
Business TV	Conference-Hours/Day (10^{3})	41	115	135	150	155
Viewer Choice TV*	Program-Seconds/Year (10^{12})	0	0	0.86	1.70	4.0

* This is an example based on numerous assumptions—see text.
Source: Booz-Allen Analysis

2.6.2 Busy Hour Analysis

Traffic projections have been developed for the various categories of voice, data, and video traffic. These projections measure the total expected amount of traffic generated each year or each day for each category. In designing telecommunication systems, it is necessary to design for peak traffic, taking into account the demand fluctuation at different times of the day. The generally-accepted practice is to evaluate traffic rates during the busy hour. These busy hour rates are then used to size the communications network.

There are four steps that are taken to convert annual traffic volumes to busy-hour traffic. First, the MTS demand forecast is split into business and residential traffic because these traffic segments have different busy hours. The annual traffic volumes for all the demand categories are then converted into average hourly traffic. Third, peak factors are computed which represent the relationship between the busy hour and average hourly traffic of each category. These peak factors are then multiplied by the average hourly traffic to obtain busy-hour traffic.

The MTS traffic forecast is made based upon the total number of MTS calls completed per year. The data sources that were used to obtain yearly call statistics do not split the traffic into business and residential calls. This split needs to be done in order to complete the MTS busy-hour analysis since the busy-hour characteristics of residential and business traffic differ significantly. IT&T's study (ref. 1) estimated the mix of residential to business long-distance traffic for the 1980s as 46/54 and for the 1990s as 43/57. This analysis was based on the relative growth rates of residential and business main telephones. The 43/57 residential to business traffic ratio is used for our analysis.

Using this MTS traffic mix, projections for both business and residential MTS traffic are included in our summary charts. The next step in the analysis is the conversion of the annual traffic projections into average hourly traffic. These conversions are based on the number of active days per year for each category. The business-oriented categories are active 250 days of the year, while the other categories are active 365 days of the year. The annual traffic volumes are divided by the active days to give average daily traffic. A further division by 24 gives average hourly traffic. These average hourly traffic projections are shown in figure 2-135.

FIGURE 2-135
Average Hourly Traffic

DS0s	Active Days Per Year	Units	Average Hourly Traffic 1991	1996	2001	2006	2011
Voice							
MTS (Business)	250	Call-seconds Per Hour (10^9)	2.2	2.9	3.8	5.6	8.3
MTS (Residential)	365	Call-seconds Per Hour (10^9)	1.15	1.45	1.95	2.9	4.3
Private Lines	250	Voice Channels (10^6)	1.30	1.80	2.1	1.70	1.40
800	250	Call-seconds Per Hour (10^9)	0.43	0.65	0.93	1.25	1.65
900	250	Call-seconds Per Hour (10^9)	0.0078	0.0135	0.020	0.026	0.032
Private Networks	250	Call-seconds Per Hour (10^9)	0.120	0.120	0.165	0.33	0.48
Data							
Facsimile	250	Call-seconds Per Hour (10^9)	0.28	0.58	0.160	0.040	0.053
E-Mail	250	Gigabits Per Hour	0.190	67	3700	18000	38000
Terminal Operations	250	Terabits Per Hour	0.47	0.85	1.35	2.0	2.9
On-Line Info. Services	250	Gigabits Per Hour	0.52	1.40	3.0	7.1	17.5
EFT	250	Terabits Per Hour	0.110	0.34	0.58	0.67	0.69
EDI	250	Terabits Per Hour	0.033	0.081	0.160	0.185	0.190
Video							
Network Broadcast	365	Video Channels	30	36	46	46	46
Cable TV	365	Video Channels	140	195	300	440	520
Education TV	250	Video Channels	48	60	87	120	150
Business TV	250	Conference-Hours (10^3)	1.70	4.8	5.6	6.3	6.5
Viewer Choice TV	365	Program-Seconds/Hour (10^9)	0	0	0.098	0.195	0.46

Source: Booz-Allen Analysis

Figure 2-136 shows the tendency of traffic during the busy hour of the day to be higher than the average hourly traffic. These parameters, commonly used in traffic computatations, are peaking factors. The peaking factor is defined as the ratio of the traffic carried in the peak hour to the day's traffic averaged over the 24 hours. The factors used here are based on analysis found in previous IT&T studies completed for NASA (IT&T, U.S. Telephone and Telegraph Corp. 1979, vol. 2; IT&T, U.S. Telephone and Telegraph Corp. 1983, vol. 2) which are updated to reflect our choice of demand categories and changes in technology and the relevant markets.

2.6.2.1 Voice Peak Factors

The MTS traffic demand is split into its residential and business components because the two have different hourly traffic distributions. As demonstrated in the previous studies, the worst case scenario for MTS traffic is measured by adding the business busy hour traffic to the residential traffic that occurs during that time. The following discussion updates and summarizes the methodology found in the IT&T report (IT&T, U.S. Telephone and Telegraph Corp. 1979, vol. 2).

FIGURE 2-136
Busy Hour (Peak) Factors

DSOs	Busy Hour (Peak) Factors 1991	1996	2001	2006	2011
Voice					
MTS (Business)	2.8	2.8	2.8	2.8	2.8
MTS (Residential)	0.4	0.4	0.4	0.4	0.4
Private Lines	1.0	1.0	1.0	1.0	1.0
800	2.8	2.8	2.8	2.8	2.8
900	2.8	2.8	2.8	2.8	2.8
Private Networks	2.8	2.8	2.8	2.8	2.8
Data					
Facsimile	2.0	2.0	2.0	2.0	2.0
E-Mail	1.8	1.8	1.8	1.8	1.8
Terminal Operations	2.0	2.0	3.0	3.0	3.0
On-Line Info. Services	2.0	2.0	3.0	3.0	3.0
EFT	2.0	2.0	2.0	2.0	2.0
EDI	2.0	2.0	2.0	2.0	2.0
Video					
Network Broadcast	1.0	1.0	1.0	1.0	1.0
Cable TV	1.0	1.0	1.0	1.0	1.0
Educational TV	1.0	1.0	1.0	1.0	1.0
Business TV	2.8	2.8	2.8	2.8	2.8
Viewer Choice TV	0.4	0.4	0.4	0.4	0.4

Sources: IT&T, U.S. Telephone and Telegraph Corp. 1979 & 1983

Nearly all of the residential MTS traffic occurs during the 16 hours between 8 a.m. and midnight. The peak hours are between 7 p.m. and 11 p.m. because these are the times that members of the household are present and because of lower long-distance tariff rates. Because of these reasons, 80 percent of the day's residential traffic is carried during these four hours. The other 20 percent of residential traffic is nearly all carried in the twelve hours from 8 a.m. to 7 p.m. and 11 p.m to midnight, yielding 1.67 percent of the day's traffic in each of the 12 non-busy hours.

The business peak hours are usually estimated as being from 10 a.m. to noon and from 1 p.m. to 3 p.m. Ref. 1 estimates that 11.67 percent of the business traffic is carried in these busy hours. This percentage yields a peaking factor of 2.8 for business MTS. The peaking factor for residential MTS during the business busy hour is 0.4.

The peaking factor for private lines is 1.0 since they are generally leased on a full-time basis and demand full-time access throughout the 24-hour period. The busy hour characteristics of 800 and 900 services are similar to business MTS and so a peaking factor of 2.8 is used.

2.6.2.2 Data Peak Factors

All of the data categories that are addressed use a mix of switched and dedicated transmission facilities. Business data traffic that uses switched services shows traffic characteristics similar to business MTS. Fax traffic is a very good example of this. Business data traffic that uses dedicated services has a 1.0 peaking factor similar to private lines.

Peaking factors resulting from real-time transmission of data are significantly higher than for deferred data transmission modes. Real-time transmission occurs during the busiest time of the day and so traffic during the busy hour is significantly larger than the average hourly traffic. When data transmission is deferred, as is the case with many of the EFT and EDI transmissions, the data that is sent at non-peak times tends to spread the traffic flow over the course of the day and brings the peaking factor closer to 1.0.

The data peaking factors shown in Figure 2-136 reflect a combination of the effects that the mix of switched/dedicated and real-time/deferred transmission have on the traffic categories.

2.6.2.3 Video Peak Factors

The first three video categories, Network Broadcast, Cable TV, and Educational TV, are assumed to require full-time dedicated service with continuous access to the communication facilities. The peak factor for these categories is 1.0.

Based on the busy hour analysis in ref. 1 for video conferencing and comparisons to business MTS traffic, a peaking factor of 2.8 is estimated for business TV. The analysis in ref. 1 assumes a uniform traffic distribution over a 10-hour business day for the Eastern and Central Time Zones constituting 50 percent of the traffic. A similar distribution is assumed for the Western and Mountain Time Zones which constitutes 25 percent of the traffic, displaced by three hours. The other 25 percent of the traffic is an east-west component uniformly distributed over the seven overlapping business hours in the two other displaced periods.

2.6.2.4 Busy Hour Traffic Projections

Busy hour traffic projections are obtained by multiplying the average hourly traffic projections in figure 2-135 by the peak factors in figure 2-136. These projections are shown in figure 2-137.

2.6.3 Traffic Projections in Equivalent DS0s

To compare the relative traffic intensities of the voice, data, and video categories, it is convenient to convert the busy-hour traffic volumes into a common unit. Figure 2-138 summarizes the results of this conversion into busy-hour DS0s. For convenience, Figure 2-139 shows the percentage of each kind of traffic for each year.

A conversion from call-seconds per hour to DS0s is made for business MTS, residential MTS, 800 service, 900 service, private networks, and facsimile. Dividing call-seconds per hour by 3600 converts this hourly traffic volume to simultaneous call-seconds. These simultaneous call-seconds are comparable to simultaneous calls, which are equivalent to DS0s. Private lines are already measured in voice channels (DS0s).

FIGURE 2-137
Busy Hour Traffic Projections

DSOs	Units	Busy Hour Traffic Projections 1991	1996	2001	2006	2011
Voice						
MTS (Business)	Call-seconds Per Hour (10^9)	6.2	8.1	10.5	15.5	23
MTS (Residential)	Call-seconds Per Hour (10^9)	0.46	0.58	0.78	1.15	1.70
Private Lines	Voice Channels (10^6)	1.30	1.80	2.1	1.70	1.40
800	Call-seconds Per Hour (10^9)	1.20	1.80	2.6	3.5	4.6
900	Call-seconds Per Hour (10^9)	0.022	0.038	0.056	0.073	0.090
Private Networks	Call-seconds Per Hour (10^9)	0.34	0.34	0.46	0.92	1.35
Data						
Facsimile	Call-seconds Per Hour (10^9)	0.56	1.15	0.32	0.080	0.105
E-Mail	Gigabits Per Hour	0.34	120	6700	32000	68000
Terminal Operations	Terabits Per Hour	0.94	1.70	4.1	6.0	8.7
On-Line Info. Services	Gigabits Per Hour	1.05	2.8	9.0	21	53
EFT	Terabits Per Hour	0.22	0.68	1.15	1.35	1.40
EDI	Terabits Per Hour	0.066	0.160	0.32	0.37	0.38
Video						
Network Broadcast	Video Channels	30	36	46	46	46
Cable TV	Video Channels	140	195	300	480	520
Educational TV	Video Channels	48	60	87	120	150
Business TV	Conference-Hours (10^3)	4.8	13.5	15.5	17.5	18.0
Viewer Choice TV	Program-Seconds Per Hour (10^9)	0	0	0.039	0.078	0.18

* This is an example based on numerous assumptions—see text.

Source: Booz·Allen Analysis

FIGURE 2-138
Busy Hour DSOs

	Units	DS0 Conversion Factor	DS0 Units	Busy Hours DS0s 1991	1996	2001	2006	2011
Voice								
MTS (Business)	Call-seconds Per Hour (10^9)	0.2778	DS0s (10^6)	1.70	2..3	2.9	4.3	6.4
MTS (Residential)	Call-seconds Per Hour (10^9)	0.2778	DS0s (10^6)	0.130	0.160	0.22	0.32	0.47
Private Lines	Voice Channels (10^6)	1.00	DS0s (10^6)	1.30	1.80	2.1	1.70	1.40
800	Call-seconds Per Hour (10^9)	0.2778	DS0s (10^6)	0.33	0.50	0.72	0.97	1.30
900	Call-seconds Per Hour (10^9)	0.2778	DS0s (10^6)	0.0061	0.0105	0.0155	0.020	0.025
Private Networks	Call-seconds Per Hour (10^9)	0.2778	DS0s (10^6)	0.094	0.094	0.130	0.26	0.38
Data								
Facsimile	Call-seconds Per Hour (10^9)	277.78	DS0s (10^3)	155	320	90	22	29
E-Mail	Gigabits Per Hour	0.00434	DS0s (10^3)	0.00150	0.52	29	140	300
Terminal Operations	Terabits Per Hour	4.34	DS0s (10^3)	4.1	7.4	18.0	26	38
On-Line Info. Services	Gigabits Per Hour	0.00434	DS0s (10^3)	0.0046	0.0120	0.039	0.091	0.23
EFT	Terabits Per Hour	4.34	DS0s (10^3)	0.95	3.0	5.0	5.9	6.1
EDI	Terabits Per Hour	4.34	DS0s (10^3)	0.29	0.69	1.40	1.60	1.65
Video								
Network Broadcast	Video Channels	*	DS0s (10^3)	29	35	14.5	14.5	14.5
Cable TV	Video Channels	*	DS0s (10^3)	135	18.5	55	81	96
Educational TV	Video Channels	*	DS0s (10^3)	46	5.8	17.0	22	28
Business TV	Conference-Hours (10^9)	*	DS0s (10^3)	440	180	150	190	195
Viewer Choice TV**	Program-Seconds/Hour (10^9)	12222	DS0s (10^3)	0	0	480	950	2200

Note: * The DS0 conversion factors for these video categories change as video compression factors change.
** This is an example based on numerous assumptions—see text.

Source: Booz·Allen Analysis

FIGURE 2-139
Busy Hour DSO Percentages

DSOs	Busy Hour Traffic Projections 1991	1996	2001	2006	2011
Voice					
MTS (Business)	38.9	42.3	44.8	53.3	59.9
MTS (Residential)	3.0	2.9	3.4	4.0	4.4
Private Lines	29.7	33.1	32.5	21.1	13.1
800	7.6	9.2	11.1	12.0	12.2
900	0.1	0.2	0.2	0.2	0.2
Private Networks	2.2	1.7	2.0	3.2	3.6
Data					
Facsimile	3.5	5.9	1.4	0.3	0.3
E-Mail	0	0	0.4	1.7	2.8
Terminal Operations	0.1	0.1	0.3	0.3	0.4
On-Line Info. Services	0	0	0	0	0
EFT	0	0.1	0.1	0.1	0.1
EDI	0	0	0	0	0
Video					
Network Broadcast	0.7	0.6	0.2	0.2	0.1
Cable TV	3.1	0.3	0.9	1.0	0.9
Educational TV	1.1	0.1	0.3	0.3	0.3
Business TV	10.1	3.3	2.3	2.4	1.8
Viewer Choice TV*	–	–	–	–	–
Total**	100	100	100	100	100

Source: Booz·Allen Analysis

* Since Viewer Choice numbers are presented only as as example, they are not included in the total

** Sums of columns may not add to exactly 100% due to rounding.

Data traffic measured in gigabits or terabits per hour are converted by calculating the number of 64 kb/s DSOs needed to satisfy the demand.

Compression factors and the advent of HDTV have to be taken into account to convert video channels to DSOs. Figure 2-140 details the breakdown of the video traffic in each category into identifiable segments which allow different levels of compression. Figure 2-141 identifies the number of DSOs that each video category demands in the 1991 to 2011 time frame. These figures are discussed in the following paragraphs.

FIGURE 2-140
Video Traffic Category Percentages

Year	Network Broadcast		Cable TV		Educational TV		Business TV			Viewer Choice TV
	NTSC	HDTV	NTSC	HDTV	NTSC	HDTV	Limited Motion	Limted Full Motion	Full Motion	ADSL
1991	100%		100%		100%		62%	26%	12%	100%
1996	100%		100%		100%		65%	24%	11%	100%
2001		100%	50%	50%	50%	50%	55%	31%	14%	100%
2006		100%	50%	50%	50%	50%	50%	34%	16%	100%
2011		100%	50%	50%	50%	50%	49%	35%	16%	100%

Source: Booz·Allen Analysis

FIGURE 2-141
Video Traffic DSO Conversion Factors

Year	Network Broadcast		Cable TV		Educational TV		Business TV			Viewer Choice TV
	NTSC	HDTV	NTSC	HDTV	NTSC	HDTV	Limited Motion	Limted Full Motion	Full Motion	ADSL
1991	960		960		960		3	12	720	44
1996	960		96		96		2	6	96	44
2001		320	48	320	96/48	320	2	6	48	44
2006		320	48	320	48	320	2	6	48	44
2011		320	48	320	48	320	2	6	48	44

Source: Booz·Allen Analysis

For the network broadcast category, FCC rulings on the introduction of HDTV point to a conversion from current National Television System Committee (NTSC) broadcasts to total HDTV transmission by 2001. The networks are currently using one transponder to broadcast one analog channel, or the equivalent of 960 DS0s. With the conversion to digital HDTV by 2001, each channel will require 320 DS0s, reflecting anticipated compression to 20 Mb/s.

The cable industry is also currently using one transponder per video channel, or the equivalent of 960 DS0s. With video compression allowing the cable channel bandwidth to decrease from 60 Mb/s to 6Mb/s, by 1996 the cable channel should only demand 96 DS0s. This assumes, of course, that the CATV industry makes the conversion by then. We project a further increase in compression technology for NTSC by the end of the century, allowing 48 DS0s (3 Mb/s) to be used. This reduction from 6 Mb/s to 3 Mb/s would require cable headends to change their codecs. We assume that this will be economically attractive to cable operators because it would allow them to conserve bandwidth on their cable distribution systems; it is also assumed that a box to convert from a 6 Mb/s encoding scheme on the national distribution system to a 3 Mb/s encoding scheme for the local distribution system would not be essentially less expensive than changing the codec and putting the distributed picture directly on the cable (Schiff 25 August 1992).

As projected with the network broadcast category, HDTV will be a factor by 2001. Since the cable industry is not required by the FCC to switch to HDTV and all the cable channels do not need the quality of HDTV, the switch will not be as dramatic. We estimate that in 2001 50 percent of cable channels will be HDTV demanding 320 DS0s and 50 percent will still be NTSC demanding 48 DS0s per channel. The cable channels requiring HDTV will primarily be the movie, sports, and news channels.

Educational TV will take advantage of compression and HDTV technology as soon as it is technically feasible and the pricing of the transmission facilities and equipment make it economically feasible. The cable market provides a useful example of the status of these factors and so we use the same compression and HDTV assumptions as for cable, with one exception. Because of the difference between the for-profit cable industry and the generally nonprofit education industry, we assume that the transition from 6 MB/s coding of NTSC pictures to 3 MB/s will be slower. In 2001, we assume that the 50 percent of the educational TV channels that are NTSC will be evenly divided between 6 MB/s and 3 Mb/s codecs; for the other years, we assume the same division and transmission rates as for cable TV.

For business TV, we use separate compression ratios for the three market segments we examined: limited motion, limited full-motion, and full-motion video. The numbers of DS0s for each picture quality are summarized in 2-140 (Schiff 14-15 May 1992). Figure 2-140 shows the percentage of total conference-hours used for each category. These are obtained from the components of the adjusted projections shown in figure 2-132.

For Viewer Choice TV, we use bit rates described for ADSL to convert to DS0s (Boyd 14-15 May 1992). The midpoint of the range of 1.6 Mb/s to 4 Mb/s described for this local-loop service is 2.8 Mb/s. Dividing this bit rate by 64 kb/s yields an estimated 44 DS0s for each VOD signal.

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3.0 TELECOMMUNICATIONS INFRASTRUCTURE STATUS AND PLANS

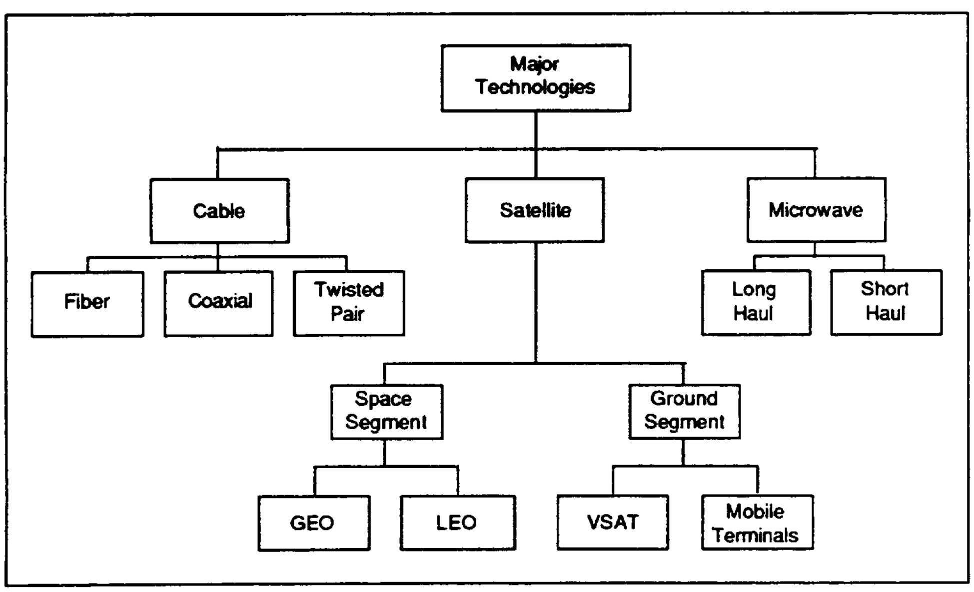
The U.S. domestic communications infrastructure relies on several transmission technologies with complementary capabilities. In addition to complementing one another, transmission media compete, because most media provide alternative means of implementing the same network application. The adoption of communications improvements in the marketplace depends ultimately on the technologies' abilities to meet certain requirements. Some of these requirements are interconnectivity with the existing infrastructure; demand for improved services; development cost and complexity; and production, installation, and maintenance costs (Congress of the United States 1990).

3.1 METHODOLOGY

This section outlines the approach taken to assess the status, plans, capacity, and installation costs of the major traffic-carrying portions of the U.S. domestic communications infrastructure. This information will assist designers of NASA's communications programs in developing and investigating advanced, high-risk technologies that fall outside the sponsorship capability of the private sector.

The first step in performing this task was to identify the major traffic-carrying portions of the U.S. domestic communications infrastructure. The breakdown presented in figure 3-1 shows three technologies: cable, satellite, and microwave radio. These form the bulk of the domestic communications infrastructure. Figure 3-1 also identifies the major subtechnologies within each technology.

FIGURE 3-1
Breakdown of Domestic Communications Technologies



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- Cable includes fiber optics, coaxial cable, and twisted pair.
- Satellite transmission technology is addressed in terms of three areas that overlap in technology and equipment but serve largely distinct applications. These technologies can be broken down into the space segment and ground segment. The space segment refers to the satellite communications technology and the orbital height, i.e., geosynchronous (GEO) or LEO. The ground segment refers to antenna technology such as small receivers, antennas, and VSAT.
- Microwave radio consists of long-haul and short-haul frequencies.

Each of the three communication technologies offers capabilities that suit it to certain communications needs. Although customer needs influence technology development, they are not the sole driving factor. Universities, research institutions, corporations, and government agencies research and develop communications alternatives and technology advancements. These advances can offer capabilities the market is not yet able to use. Further, Federal regulations such as the number of orbital positions available to GEO satellites and the assigned frequency bands for transmission affect the technologies' use in the domestic infrastructure. To assess the status, plans, capacities, and costs of technologies used in the domestic communications infrastructure, it is necessary to consider technology improvements coming from the demand and supply side: those that are a direct result of market pressures to provide a service and those that provide a service a market grows into later.

The second step of the assessment process involved data research and review of literature from marketing agencies, technical reports and journals, industry trade magazines, government statistics and reports, and corporate annual reports. Discussions with experts who have direct industry knowledge provided additional insight into the various technologies. Client and expert review identified and expanded the knowledge base and increased the accuracy of the assessments. The reference section at the end of this chapter lists the publications used for the investigation.

The third step was to assess each of the three technology categories. The literature examined in step 2 helped to identify the role of each technology in the infrastructure. The assessment provided information about the capabilities of each technology and its capacities, status, and degree of use in the domestic infrastructure. Also analyzed for each technology were carriers' plans and the cost relationships that influence these plans. Sections 3.2 through 3.4 provide results of this step.

3.2 CABLE FACILITIES

This section presents an assessment of the status, plans, capacity, and costs of the most commonly used forms of cable technology. It includes an assessment of fiber optics, coaxial cable (including duplex technology), and twisted-pair copper wire (including compensated twisted pair).

3.2.1 Fiber Optic Cable

Use of fiber optic cable has grown substantially throughout the 1980's and into the 1990's. It has progressed beyond long-haul, common-carrier telecommunications into cable TV, research networks, private networks, and local area networks. The following paragraphs examine the current status, plans, capacity, and costs of fiber optics in the major domestic traffic markets: telecommunications and cable TV (CATV).

3.2.1.1 Fiber Optic Distribution in the Telecommunications Market. Fiber cable is by far the leading cable technology in the U.S. domestic long-haul communications infrastructure. Today, after years of conversion from coaxial cable and microwave by interexchange carriers, long-distance phone service in the United States is primarily carried on single-mode optical fiber, with only a few carriers maintaining digital microwave communications in areas with rough terrain or low population density. The conversion to fiber from other technologies began in 1983. Fiber installation proceeded rapidly as a result of the 1982 AT&T divestiture that accelerated competition and the increase in capacity and quality that fiber provided. For competitive reasons, long-distance carriers began installing fiber in their networks and marketing their services as providing connections with clarity and quality superior to older technologies. This competitive environment resulted in significant expenditures of capital resources (i.e., more than $5 billion as of 1986) by nine of the nation's leading long-distance companies to provide long-distance fiber communications. By 1987, the bulk of the long-distance phone service had been converted to fiber. Today, Sprint, with its 23,000-mile all-fiber network, provides long-distance service that has been entirely fiber since 1988. MCI reported that as of 1990 its domestic network was 99 percent digital and targeted at 100 percent by February 1992. The majority of MCI's network is fiber with digital radio remaining in some locations. As of 1988, AT&T had more than 23,000 fiber route miles in place and was planning to lay an additional 10,000 miles by 1993. By December 1991, AT&T had installed 31,400 fiber route miles of its planned 33,000 fiber route miles. AT&T plans for its entire network to be digital by 1993 based mainly on fiber, with only a small fraction of the digital microwave radio remaining (Data Pro August 1991). Other interexchange carriers, such as WilTel, RCI Long Distance, ATC, Consolidated Network Inc., Mutual Signal Corporation, Communications Transmission Inc., and Norlight, accounted for an additional 22,000 fiber route miles across the country by 1988 (Data Pro August 1991; *Network World* 25 November 1991) .

Figure 3-2 is a map of U.S. fiber optic routes. It depicts the aggregated fiber backbone of all the long-distance communications carriers and clearly shows that long-haul fiber service is available to all of the main population centers in the contiguous United States (Kessler Marketing Intelligence 1989; *Network World*).

Local exchange carriers began installing fiber around 1987, the same time as long-distance carriers began to slow their investments (Data Pro August 1991; *Telephony* November 1990; *Fiber Optics* January 1991). The Department of Commerce estimated that the Bell Operating Companies (BOCs) deployed about 1.5 million miles of fiber by the end of 1988. These lines connect the carrier to the IEC networks and interconnect LEC central offices. Today, the LECs have virtually completed their interconnection plans.

Even with all the expansion by the IECs and LECs, the use of fiber has been almost completely confined to interoffice trunking. Penetration into the local loop, where traffic volume is lower, distances are shorter, and costs per subscriber line have been high (currently around $1600) has been slow (*Telephony* 18 September 1990; *Fiber Optics* ; *IEEE Communications* November 1988).

3.2.1.2 Fiber Optic Distribution in the Cable TV Market. Use of fiber optics in the U.S. CATV market is very limited. Coaxial cable still serves as the predominant medium for transmission of cable programming.

3.2.2 Fiber Status and Plans

As mentioned, use of fiber optics in the long-distance networks has expanded to a point where most traffic is carried over fiber optic trunks. The three major long-distance carriers have extensive fiber networks: Sprint's network is 100 percent fiber; MCI's is 100 percent digital (though mostly fiber, it includes some digital radio); and AT&T has 31,400 fiber route miles in its 62,500 route-mile domestic network (Data Pro August 1990; *Network World* 25 November 1991).

FIGURE 3-2
Long-Haul U.S. Fiber Optic Communications Infrastructure

Sources:

1. "AT&T Earmarks $3b for 1992 Network Upgrades," *Network World*, 25 November 1991
2. "Fiber Optic Long-Haul Systems Planned and in Place," *Kessler Marketing Intelligence*, 1987 and 1989
3. *Data Pro reports on Communications Alternatives, August 1990*
4. "Optical Fiber Illusions," *Forbes*, 3 November 1986

AT&T plans to spend $3 billion in 1992 to upgrade and expand the reach of its global network. AT&T spent $20 billion in the last 8 years for these upgrades. The bulk of the new money used will be for network improvements. AT&T vice president of strategic planning John Petrillo said, "We need more fiber; economics and sound quality have made fiber the transmission technology of choice for us." AT&T plans to have an entirely digital network by 1993, with half of its 62,500 route-mile domestic network composed of coaxial cable, for low-use lines, and microwave in rough terrain. AT&T uses satellite facilities and undersea fiber and coaxial cables to carry intercontinental traffic (*Network World* 25 November 1991). Installation of new fiber cable in the domestic long-haul market has slowed considerably. Transmission investment by the IECs largely will be in the form of replacement for cables and improved electronics.

The LECs have extensive fiber networks that connect to the IECs and interconnect central offices. The local loop is the only place where fiber is not already the dominant technology. The LECs look at the local loop as the next place to bring fiber, thus establishing end-to-end fiber communications. The progression of fiber in the local loop is being driven by the prospects of providing integrated voice, data, and video services in businesses and homes that require the bandwidth available with fiber (*Telephony* November 1990; *Fiber Optics* ; *IEEE Communications* November 1988).

There are more than 125 million telephone access lines in the United States, virtually all connected to the public switched network with copper wires and cables. Some 3 to 4 million new lines are installed each year, and another 2 to 3 million lines are rehabilitated each year. With the potential services that fiber cable can bring to these users, there is tremendous incentive to use fiber in the local loop. The potential market is considered to be worth as much as $4 to $5 billion annually (*Fiber Optics* January 1991). Additionally, recent legislation, changes in FCC rules, and court victories have removed the barriers preventing the RBOCs from providing information services. LECs are now permitted to provide such services as electronic yellow pages, distributed image processing, and video programming (*Washington Technology* 7 November 1991; Business Communications Review 1991). For these reasons, many of the LECs believe that the sooner fiber is deployed in the local loop the faster new services can be made available to customers.

Competitive imperatives and opportunities are driving the LECs to increase the bandwidth that can be delivered through the local loop. As Philip Sirlin of Strategic Systems Group explains, LECs perform two basic functions: aggregation of traffic from individual customers and transport of aggregated traffic to IEC points of presence and between central offices. The LECs' highly profitable transport functions attract competition because of intra-LATA presubscription. Profit on the LECs' aggregation functions is also eroding. IEC bypass offerings are "skimming the cream" of traffic from large customers who aggregate their own traffic with private branch exchanges (PBXs). CATV customer demands will lead cable companies to encroach on the LECs' aggregation business as well. CATV cables reach individual homes, as do local loops. The more profitable pay-per-view (PPV) technologies increasingly require two-way transmission, billing, and switching to permit pause, scheduling, and selection features demanded by users.

The LECs' primary competitive advantage is their large installed base of subscriber lines. But PCN technology is likely to prove a less capital-intensive means of connecting subscribers to voice networks. The reduction in capital requirements made possible by PCN removes an important barrier to industry entry that protects the LECs.

All this competitive pressure means that revenue growth must come from new services. The consensus of industry sources is that the vast preponderance of subscriber revenue will be generated by PPV video programming. Video telephony, remote medical examination, education, teletex, and telecommuting are expected to be minor revenue generators compared to video programming.

Because of these forces, nearly all LECs have had plans since 1987 or 1988 to bring fiber into the local loop. NYNEX, for example, began planning their fiber in the local loop as early as 1988 (*Telephony* November 1990; *Fiber Optics*). However, fiber in the local loop has not progressed as fast as in the long-haul area. The tremendous costs involved in replacing millions of miles of copper cable with fiber cable makes the task tremendously capital intensive. It is only economically viable when fiber costs make it possible to begin large-scale installation in the local loop. Therefore, fiber to the home (FTTH) installation, for the time being, has been replaced by fiber to the curb (FTTC) installation. All RBOCs are involved in evaluation of FTTC networks, leaving the final feet of existing cable in the ground (*Telephony* November 1990; *Fiber Optics*). Richard Snelling, executive vice president of Southern Bell, said in April 1990 that "FTTC is economical today, not 1992 or 1995" (*Telephony* November 1990). Ameritech, Southwestern Bell, NYNEX, US West, BellSouth, Bell Atlantic, Alltel, Pacific Telesis, and GTE all have installed evaluation networks of FTTC, or even FTTH in a few instances. Many of these evaluation networks are providing data, video, ISDN, CATV transport, CATV PPV, broadband services, and ordinary telephone service (*Telephony* November 1990; *Fiber Optics*). Additionally, most LECs have plans to install or replace copper with fiber for most new construction and many rehabilitation projects, thus increasing the size of their FTTC networks. The LECs believe that by 1993, fiber will be cost competitive with copper (*Telephony* November 1990; *Fiber Optics*).

Several issues are now pressing the cable TV industry into moving toward fiber networks. The major network broadcast corporations (i.e., NBC, ABC, and CBS) are investigating with the IECs the transmission of network programming over their fiber networks. This move could pave the way for the high-bandwidth transmission necessary for HDTV. When the LECs have installed their fiber networks and have permission from the Government, it will be possible to receive network programming over fiber optics. These issues create an environment that drives the cable TV industry to use fiber optics in their networks.

LANs increasingly use fiber optics. Today more than 20 percent of all new LAN installations use fiber systems. This percentage will grow as the cost of optical equipment decreases.

3.2.3 Fiber Optic Technology and Capacity Trends

There are two basic types of optical fiber: multimode, which includes stepped index and graded index, and single mode. Multimode fiber is used for medium- and short-haul applications.

With stepped-index optical fiber, reflection of light takes place at the boundary between materials of uniform high-and low-refractive indices, as illustrated in figure 3-3(a). Graded-index fiber has a core whose refractive properties decrease parabolically from the center outward. The light rays propagate by refraction in a curve around the fiber optic axis, as shown in figure 3-3(b). Single-mode fiber rays follow a direct path along the fiber core, as shown in figure 3.3(c). This transmission pattern allows for increased distance between repeaters and increased information capacity because there is less destructive interference than in multimode fiber (Data Pro August 1990).

FIGURE 3-3(a)
Stepped-Index Optical Fiber

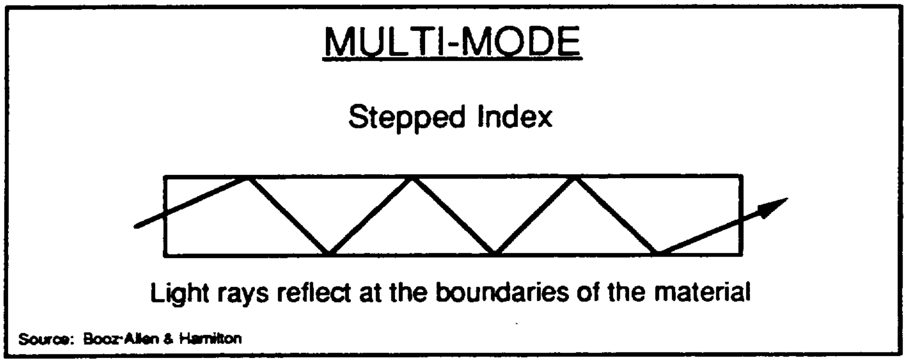


FIGURE 3-3(b)
Graded-Index Optical Fiber

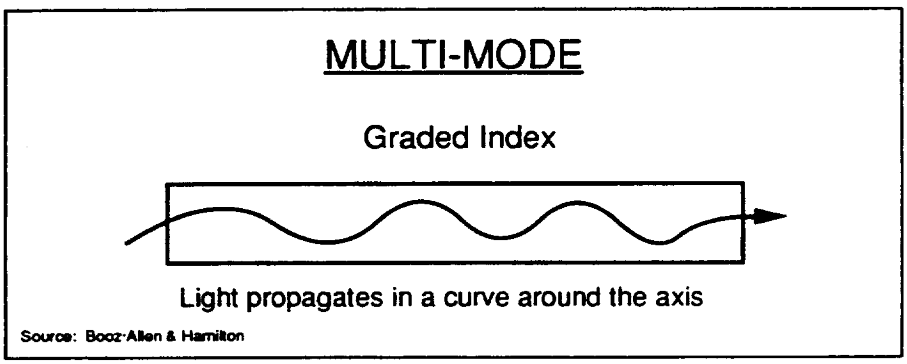
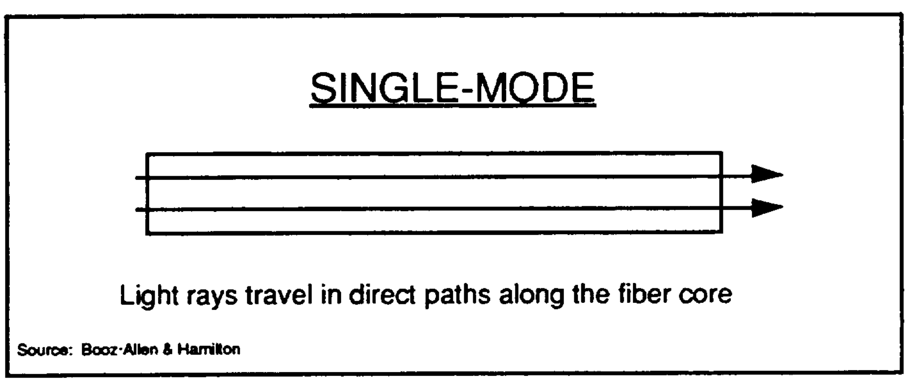


FIGURE 3-3(c)
Single-Mode Optical Fiber



Of these types of fiber, stepped index has the greatest attenuation of light, graded index the next, and single mode has the least attenuation. The attenuation factors generally dictate the uses of different types of fiber. Higher attenuation factors lead to shorter distances between repeaters. Hence, fiber with low attenuation is used for long-haul communications. With improvements in manufacturing, it is now possible to get all of the most desirable features (i.e., lower attenuation, higher achievable data rates, and lower costs) in single-mode fiber. Today, single-mode fiber, which was originally used for long-haul applications only, is the cable of choice for medium- and short-haul communications also, and very little if any stepped- or graded-index fiber is used (Data Pro August 1991).

The general distance between repeaters for long-haul communications in most current installations is about 30 miles (Data Pro August 1990). Laboratory tests show distances of 60 miles as possible for deployment. Test experiments are using repeater distances of greater than 155 miles, which shows promise for undersea cable. Figure 3-4 provides comparisons between multimode and single-mode fiber systems.

FIGURE 3-4
Single-Mode and Multimode Fiber Have Different Features

FEATURES	MULTIMODE	SINGLE-MODE
Typical Usual Distance Between Repeaters	Up to 5 km	80 km typical
Typical Capacity	Up to 500 Mb/s	2.4 Gb/s
Traditional	Voice/Data/Image/Sensor Premises System	Long-Haul Communications Local Loop
Transmitter Cost	Less Expensive LEDs	More Expensive Lasers
Fiber Size (mm)	62.5/125, 50/125, 100/400	8.3/125, 9.0/125
Wavelength (nm)	850 to 1,310	1,300 or 1,550

Source: DataPro August 1990

When long-distance carriers began laying their fiber networks, how soon electronics with higher bandwidths would be available for use was unknown. In the mid-1980's to late 1980's, companies laid extra fiber as a means of ensuring their ability to handle demand in the future. The guiding philosophy between 1984 and 1986 was that at roughly 40 cents a fiber meter, it was more economical to lay extra fiber and be prepared for the future than to come back later and install an additional or replacement cable (*LAN Magazine* June 1987). During a 2-year period from 1984 to 1986, long-distance communications capacity expanded by 400 percent, well ahead of the 8-percent-a-year growth rate of the market (*Forbes* 3 November 1986). Since the early 1980's, more than 3.5 million miles of fiber have been laid throughout the United States. Now, only 1 million miles out of 3.5 million miles of fiber, or roughly 30 percent, are actually being used (or lighted) (FCC 1989/1990).

The first single-mode system in commercial service, deployed by MCI in 1983, used opto-electronics operating at 405 Mb/s to carry 6048 DS0s on each fiber pair. Successive improvements in laser output power, detector sensitivity, and high-speed circuitry have resulted in equipment operating at 565 Mb/s, 810 Mb/s, 1.2 Gb/s, 1.7 Gb/s, 2.4 Gb/s and 3.4 Gb/s. All are still in service. Even higher speeds are anticipated in the near future (Data Pro, August 1990).

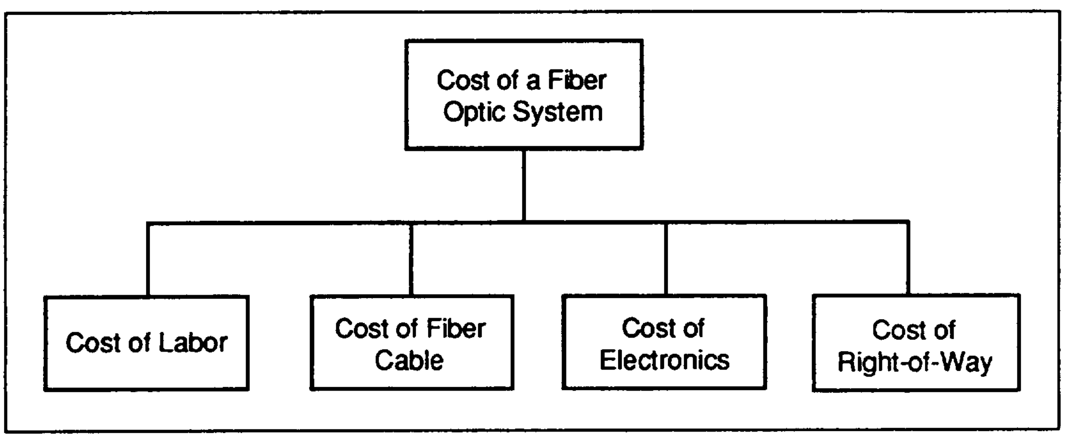
There are three ways to increase the capacity of an existing system the least expensive of which is to equip ("light up") unused fiber pairs. The second alternative is to replace the electronics (i.e., terminals and regenerators) with higher-speed equipment; the removed equipment can be reused to light up fibers on other cables. The third alternative is to use wavelength-division multiplexing (WDM), which allows simultaneous operation at different wavelengths. WDM adds about 20 percent to the system cost (Data Pro August 1990).

Synchronous Optical Network (SONET)-based systems are beginning to enter the fiber market. SONET was approved in 1988 as a standard set of specifications for building high-speed digital fiber communications networks. These standards will make integration of components from different vendors possible. This aspect alone will increase the alternatives for users and drive down prices. Currently, SONET standards have been specified for data rates up to 2.4 Gb/s. Sprint began installing SONET-based cross-connect systems in 1991. MCI plans to install SONET-based terminals and regenerators in 1992.

3.2.4 Fiber Costs

Figure 3-5 shows a breakdown of the major cost components of a fiber optic system. As shown, there are four cost components—right-of-way, labor, fiber cable, and electronics — that a company must estimate when considering the use of fiber optic systems. For the purpose of this study, right-of-way cost includes both the cost to lease right-of-way in rural areas and the cost to lease space in existing ducts in metropolitan areas.

FIGURE 3-5
Cost Breakdown of a Fiber System



Right-of-way costs vary greatly. Outside metropolitan areas, individual negotiations between the carrier and the person or firm that controls the right of way largely determine prices. Because a cable system does not require exclusive use of the land, local real estate values have little relevance. More important are uniqueness (attaching cable to a bridge or tunnel is much less expensive than using submarine cable), continuous lengths of right-of-way, amount of right of way contracted for (carriers have signed agreements with individual railroads to use thousands of miles), security from promiscuous digging (highway medians and railway beds are more secure than county roads), and provision of communications to the right-of-way holder (railroads, electric utilities, and aqueduct systems value this). In metropolitan areas, cable cannot be direct-buried as it is in rural areas, and duct systems must be used. These are very expensive to construct and permitting for their construction can be very time-consuming. An alternative is to lease space in existing duct systems, typically owned by the local telephone company or MCI, which purchased

Western Union's duct systems. Right-of-way availability has improved, at least in rural areas, due to the Federal Highway Administration's lifting of right-of-way restrictions along Federal highways. Now the states may decide whether utilities may use state-owned rights-of-way, as long as highway safety standards are maintained (Data Pro August 1990).

However, the cost of the right-of-way is not a factor in determining whether to use fiber optics or a copper-based system. Installation of a new system requires acquisition of right-of-way regardless of the technology used. Therefore, the cost of the right-of-way plays a role only in the decision to build the system at all or whether to use a system (e.g., satellites or microwave) that does not require a right-of-way. The ultimate decision to use fiber rather than copper cable comes from the analysis of the remaining costs to install a fiber optic system. The breakdown of the costs of labor, fiber cable, and electronics is split approximately in half — the costs of labor and fiber cable compose half the cost and electronics the other half (*Fiber Optics*).

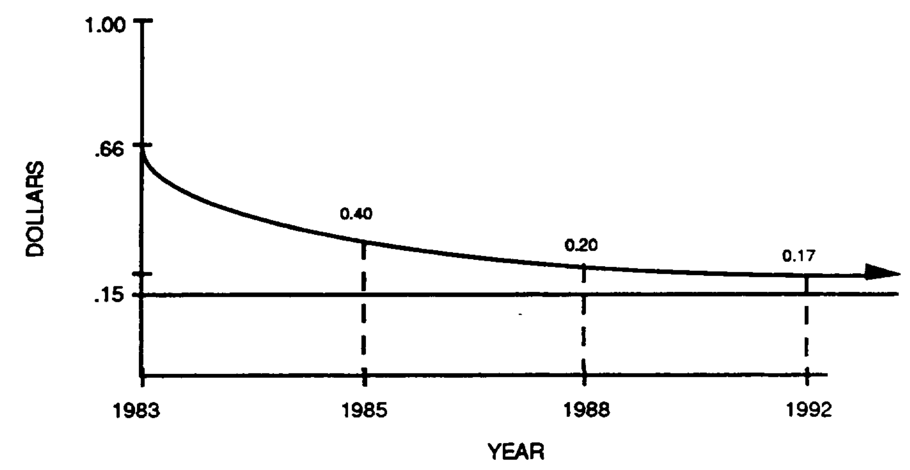
Figure 3-6 provides a comparison of the costs of cabled fiber over time. Cabled fiber has continually dropped in price over the past 15 years. Around 1978, cabled multimode fiber cost approximately $1.88 per meter; in 1983, the cost of single-mode fiber, which had become the dominant fiber medium, was about $0.66 per cabled fiber meter; in 1985, the costs were around $0.40; and in 1988, that price had dropped to around $0.20 per meter. Today cabled fiber costs around $0.17 per meter. Exact prices depend on the volume and quality of the fiber. Prices are expected to continue to fall, with some estimates of cabled single-mode fiber as low as $0.15 per meter by 1993. After 1993, costs of cabled fiber are expected to level off at $0.14 or $0.13 per meter, the bottom line of profitability for cable manufacturers (Data Pro August 1990; Shumate February 1990, 73-76; *Telecommunications Report*. Multimode fiber costs twice as much as single-mode fiber (*Telecommunications Report*). Multimode fiber is now used only in LANs where distances are less than 5 km between nodes (*Telecommunications Report*).

The break-even point between copper feeder systems and fiber was approximately 1.5 miles as of 1990. This is down from 2.5 miles in 1984 and is expected to continue to drop (*Fiber Optics*). Once fiber optic systems reach $700 to $1,100 per subscriber line, they will have reached cost parity with copper for systems of any length (*Telephony* November 1990). This is expected to occur in the 1993 to 1995 time frame. The price of fiber optic systems as of November 1990 was $1,600 per subscriber line, down from $2,200 per line in less than 2 years (*Telephony* November 1990; *Fiber Optics*).

Maintaining and upgrading fiber optic systems are easier than for copper systems because capabilities are built into the systems to allow for line testing, reconfiguration, upgrading, and provisioning of second lines to all be done through remote software control. These measures save the telephone company approximately $100 for each service call, and, therefore, fiber optic systems can be justified if one considers life-cycle cost. Even with conservative maintenance assumptions, a copper system installed today will become more expensive to maintain long before its 20-year depreciable life expires (*Fiber Optics*).

The fiber industry is characterized by a few primary suppliers and a wide range of fiber customers. Despite the range of customers, the product diversity in this industry is extremely small. Suppliers compete primarily on price, with technological advances leading to increased bandwidth, improved signal regeneration electronics, and reduced life-cycle fiber costs.

FIGURE 3-6
Cost of Purchasing Cabled Fiber Over the Years



Source: Low-Cost fiber technology strategies for the subscriber loop, Bellcore briefing, 1988

Two suppliers, AT&T and Siecor, account for 71 percent of the domestic fiber optic cable market. The table below provides a market profile of fiber cable suppliers in the United States.

Suppliers	Cable Sales	Percent
	$M	
Siecor	180	36
AT&T	171	35
Alcatel	51	10
Pirelli	30	6
Northern Telecom	24	5
BRIIntec/Br.Rex	13	3
Sumitomo	2	0
All Others	25	5

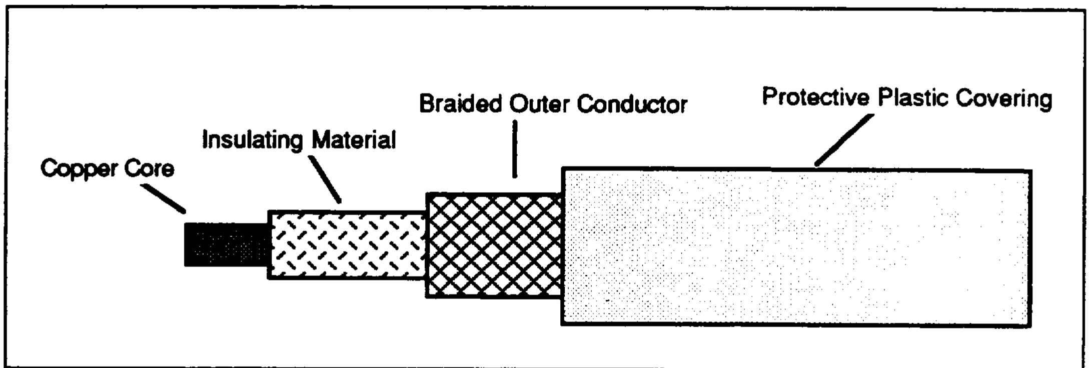
Sources: DataPro August 90; DataPro August 91; DataPro September 1991

The primary purchasers of fiber optic equipment typically have been common carriers and the Federal Government. Although the interexchange carriers historically have been the largest users of fiber optic cable, their network conversion to fiber optics is almost complete. Consequently, future growth in fiber will be fueled by demand from the Federal Government, BOCs and other LECs, LANs, and CATV. It is estimated that, by 1992, more than 20 percent of all LAN installations will be fiber based with 250,000 network nodes being served. As fiber costs decline compared to coaxial cable alternatives, CATV firms will begin to migrate toward fiber to take advantage of increased bandwidth.

3.3 COAXIAL CABLE

Coaxial cable is another transmission medium heavily used in the U.S. domestic communications market. Coaxial cable combines high bandwidth with low noise characteristics. Figure 3-7 shows a cross-section of a coaxial cable. The copper core is surrounded by insulation, then an outer conductor, and finally encased in plastic.

FIGURE 3-7
Cross-Sectional View of a Coaxial Cable



Source: Booz-Allen & Hamilton

Coaxial cable can be divided into two primary groups, digital (i.e., 50-ohm baseband cable) and analog (i.e., 75-ohm broadband cable). Figure 3-8 shows these two groups, their data rates, and typical applications.

FIGURE 3-8
Typical Applications and Data Rates of Coaxial Cable

50-OhmCable (Baseband)

- Local Area Networks
- Wide Area Networks
- Certain Long-Distance Telephone
- Feasible Data Rate–10 Mb/s

75-Ohm Cable (Broadband)

- Cable Television
- Long-Distance Telephone (using FDM)
- Feasible Data Rate – 150 Mb/s

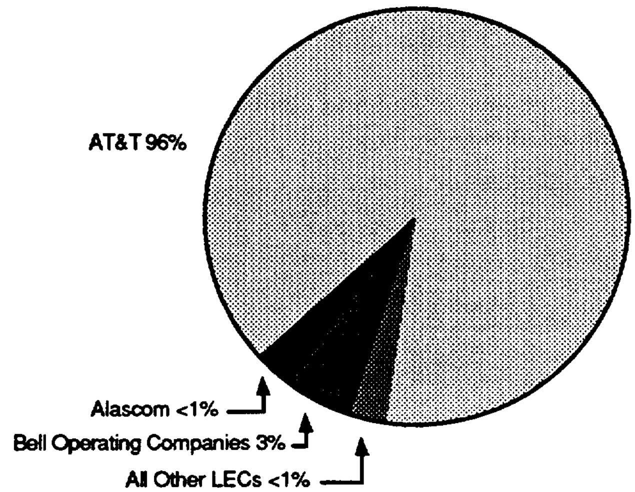
Source: DataPro August 91

The primary use of baseband coaxial cable is in LANs. Consequently, this technology is not a major component of the U.S. domestic communications market. Baseband coaxial cable typically carries a single digital channel at 10 Mb/s with an effective range without repeaters of 1 km.

Broadband coaxial cable is the most common transmission medium used in the cable TV industry. Currently more than 105,000 miles serve the industry. These networks typically have an investment cost of $100 per subscriber with thousands of subscribers per channel. CATV networks have no switching capabilities and limited interactive capabilities. Broadband cable has a bandwidth of 300 to 500 MHz and is usually installed aerially or buried.

Figure 3-9 shows the percentage of investment that has been made in coaxial cable for telecommunications by the telephone operators across the country. As shown, AT&T with 96 percent of the U.S. investment is the major user of coaxial cable (FCC 1989/1990).

FIGURE 3-9
Coaxial Cable Common Carriers



TOTAL MILES = 260,117

Source: FCC Statistics of Communications Common Carriers

Beginning in the late 1940's and continuing until the mid-1970's, AT&T viewed coaxial cable as a viable transmission option for its higher-capacity routes. As fiber optics came into its own, however, coaxial cable was quickly replaced by fiber (*Telecommunications Transmission Handbook*). Figure 3-10 shows the different types of systems AT&T has used for coaxial cable transmission. With improvements, AT&T's "L" system went from 600 channels in its L1 carrier to more than 10,800 channels in its L5 carrier.

FIGURE 3-10
AT&T "L" System Characteristics

System Type	L1	L3*	L4	L5
Maximum Design Length	4000 Miles	1000 Miles	4000 Miles	4000 Miles
Number of 4-kHz FDM VF Channels	600	1800	3600	10,800
Line Frequency	60 – 2788 kHz	312 – 8284 kHz	564 – 17,548 kHz	1590 – 68,780 kHz
Nominal Repeater Spacing	8 Miles	4 Miles	2 Miles	1 Mile
Power Feed Points	160 Miles	160 Miles	160 Miles	75 Miles

*Note the AT&T L3 system is used primarily for video.

Source: DataPro August 1991

3.4 TWISTED PAIR

Twisted pair is by far the most common type of transmission medium found in the U.S. domestic communications market. Although IECs have replaced most of their copper systems with fiber, a tremendous amount of copper in the LECs still has not been replaced. Figure 3-11 shows the miles of copper wire in the United States (FCC 1989/1990).

FIGURE 3-11
Miles of Copper Wire in the United States

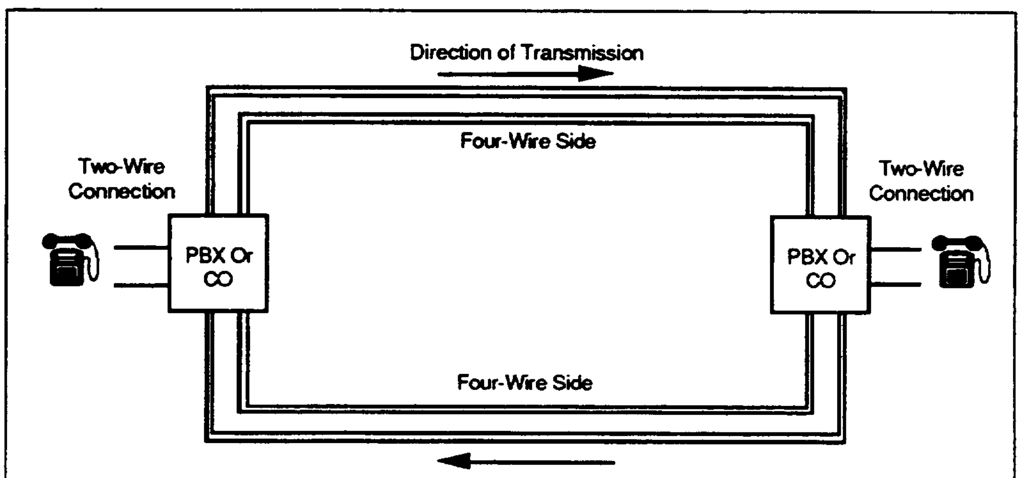
Miles of Wire	
AT&T	2,917,289
Bell Operating Companies	1,269,835,868
Other Local Exchange Carriers	228,800,133

Source: FCC Statistics of Communications Common Carriers, 1990

Twisted pair is composed of two or four insulated copper wires that are twisted to reduce interference from adjacent pairs. Quality of transmission and the distance between repeaters is a function of wire thickness. The larger wire allows for greater quality and distance; however, this is done at a higher price. Twisted pair can be used for both analog and digital transmission.

Communications requires two-way transmission; for this reason telephone networks employ two-wire and four-wire configurations. Figure 3-12 shows a typical communications network configuration. Nearly all IEC connections use four-wire links.

FIGURE 3-12
Typical Twisted-Pair Connection to IEC



Source: Booz-Allen & Hamilton

To improve copper wire's data transmission capabilities, equalization is used to reduce variation of attenuation with frequency and reduce propagation time variation with frequency. Equalization has extended the usefulness of twisted-pair transmission. A twisted pair can carry a T1 signal (i.e., 1.544 Mb/s) for short distances; it can also carry a T2 signal (i.e., 6.312 Mb/s), although T2 is rarely used.

3.5 SATELLITES

Satellite transmission is used in many parts of the world and has become an integral part of the communications infrastructure of most countries. The United States has numerous commercial satellites that provide voice, data, and video services to a wide variety of customers. Satellites are particularly well suited for point-to-multipoint communications.

The following material identifies the domestic satellite infrastructure and the basic technologies used for satellite communications. The discussion includes satellite capabilities, benefits, and drawbacks; the capacity, status, and plans of the domestic satellite carriers; and the associated costs.

3.5.1 Geosynchronous Satellite Technology

Approximately 22,300 miles above the equator, the orbital period of a satellite is 1 day, the same as the orbital period of the earth. This type of satellite is a GEO satellite or in geosynchronous orbit. A GEO satellite appears in a fixed position from any point on the earth. This is important for communications because it means that fixed (i.e., nontracking) antennas can be used for most communications. Because GEO orbits are very high, a single satellite antenna can cover a large part of the earth, providing communication capabilities to any point in the antenna pattern. Also, very few satellites are required to cover most of the earth's surface.

A major issue for GEO satellites is propagation delay. A signal takes about 120 milliseconds to travel between the satellite and the earth. For voice conversations, the round-trip propagation delay of almost half a second can be very annoying, especially if unexpected. For this reason, the use of GEO satellite transmission for voice traffic in CONUS has declined almost to zero. For data transmission, the propagation delay can be a problem for some protocols, but methods of alleviating or eliminating the problem are available.

Commercial communication satellites operate in C-band and Ku-band. Ka-band will be used by NASA's ACTS satellite. Figure 3-13 shows CCITT allocations for North America.

FIGURE 3-13
Satellite Transmission Band

Band	Uplink Frequency	Downlink Frequency	Available Bandwidth
C	5.925-6.425 GHz	3.7-4.2 GHz	500 MHz
Ku	14-14.5 GHz	11.7-12.2 GHz	500 MHz
Ka	27.5-31 GHz	17.7-21.2 GHz	3500 MHz

C-band transmissions are almost unaffected by atmospheric conditions, principally rain, whereas Ku- and Ka-band signals can be seriously attenuated by rain. Because the C-band allocation is shared with terrestrial microwave, the power flux density from C-band satellites is limited to -142 dBW/m^2 over CONUS. No such limitation applies to Ku- and Ka-band satellites, so they have been able to take advantage of technology advances in satellite power generation. The band-sharing and power limitations of C-band satellites mean that larger antennas are required, which must be located so as not to interfere with terrestrial microwave systems. This generally means outside major metropolitan areas. On the other hand, antennas for Ku-band systems can be smaller and sited much more freely.

The use of C-band preceded Ku-band because terrestrial microwave components were already available at these frequencies. For both technological and historical reasons, today distinct although overlapping areas of application for C-band and Ku-band satellites exist for domestic communications. A principal application of C-band satellites is for point-to-point video transmission. A principal application of Ku-band satellites is for data transmission, especially in private networks that require the flexibility of earth terminal placement provided at Ku-band.

All present commercial communication satellites are "bent-pipe" repeaters—they amplify and retransmit the signals they receive. By contrast, one of the purposes of NASA's ACTS system, to be launched in 1993, is to explore the uses of on-board satellite processing (Data Pro August 1990; *Network Management* November 1988). Figure 3-14 shows the present operational domestic satellites.

3.5.2 Geostationary Satellite Status and Plans

The use of Ku-band satellites continues to grow because of the attractive cost advantages of VSAT systems using higher-powered Ku-band satellites. The number of Ku-band transponders in orbit will be nearly double the number of C-band transponders by the mid- to late 1990's (Data Pro August 1990). GTE Spacenet Vice President David Fiske forecasts that Ku-band video transponder use will equal C-band use around 1995 (*Via Satellite* July 1990).

Satellite use in C-band will decline but not disappear. Higher-powered satellites, using Ku-band and, further in the future, even higher frequencies such as Ka-band, will dominate (Data Pro August 1990).

The change, however, will occur slowly. Several major satellite service providers, including Hughes Communications and GE American Communications, are committed to continued services extending through this century. According to Hughes, more than 15,000 commercial C-band installations exist at cable headends, television stations, and other businesses around the country. More than 90 percent of all domestic television stations have C-band satellite capability. This represents a significant investment in C-band terrestrial plant, ensuring continuing C-band use. There are an estimated 3 million privately-owned C-band backyard satellite dish installations. Despite a major decline in sales of home television receive-only (TVRO) equipment, caused by the scrambling of cable programming services, a significant user base still exists to keep the C-band market viable throughout this century (Data Pro August 1990).

Several new satellites carry both C-band and Ku-band transponders, permitting the implementation of networks that take advantage of the characteristics of both frequency bands. Nonetheless, the number of satellites recently launched, planned, or in construction shows an unmistakable move toward Ku-band as the dominant satellite delivery technology in the near future (Data Pro August 1990).

In its order and authorization adopted June 19, 1992, released July 7, 1992 under FCC Docket File No. 54-DSS-P/L-90 and 55-DSS-P-90, the FCC granted authority for Norris Satellite Communications, Inc., to proceed with construction, launch, and operation of the first U.S. commercial telecommunications satellite operating at Ka-band. The FCC said the authorization should promote commercial development of a frequency band that is allocated to domestic space telecommunications but is lying fallow. Norris also was authorized to construct a second satellite as a ground spare. The FCC denied a GTE Spacenet Corp. petition to deny Norris' application, which alleged technical and financial problems. The experimental NASA ACTS satellite, which operates at Ka-band, is scheduled to be launched in 1993 (*Telecommunications Report* 29 June 1992 and ACTS Project Officer).

Along with its application, Norris had petitioned for a rulemaking to reallocate 1,000 MHz of Ka-band spectrum to a "general satellite service" in which applications offered in the fixed, mobile, and broadcasting satellite services could be offered along with "personal access" satellite services. Norris saw a potential for commercial use of the uncluttered Ka-band spectrum to transmit video programming, for high-speed data networking using VSATs, and for networks linking together government and industry supercomputers.

Earlier this year, the United States proposed a general satellite service allocation at 19.7 to 20.2 GHz and 29.5 to 30.0 GHz at the World Administrative Radio Conference (WARC) on spectrum allocations. But WARC concluded that existing fixed and mobile satellite services could meet the service applications foreseen for a general satellite service.

The FCC said Norris plans to begin construction of its first satellite within 12 months of the grant of its application and to launch the satellite within 42 months. Norris estimated that construction and launch costs will be $190 million. It proposed to offer services on a non-common carrier basis. Norris requested a geostationary orbital arc assignment at 90 degrees West Longitude.

3.5.3 GEO Cost to Install

Figure 3-15 shows the costs to develop, launch, and insure a single satellite (Albert F. Caprioglio, consultant, Communications System Development, private conversation, 9 December 1991).

FIGURE 3-14
Operational Commercial Communications Satellites

COMPANY	SATELLITE	LAUNCH DATE	END OF LIFE	FREQ. BAND	BW MHZ	NO. OF TRANSPONDERS
ALASCOM	AURORA 1	10/82	10/92	C	36	24
AT&T	TELSTAR 301	1983	1993	C	36	24
	TELSTAR 302	1984	1994	C	36	24
	TELSTAR 303	1985	1995	C	36	24
	TELSTAR 401	1993	2005	C	36	24
				Ku	54	16
	TELSTAR 402	1994	2006	C	36	24
				Ku	54	16
COMSAT	COMSTAR 2	1978	+ 1985	C	36	24
	COMSTAR 4	1981	+ 1988	C	36	24
	SBS1	1980	+ 11/87	Ku	54	10
	SBS2	9/81	+ 9/88	Ku	54	10
GE AMERICOM	SATCOM 3R	11/81	+ 11/91	C	36	24
	SATCOM 4	1/82	11/92	C	36	24
	SATCOM 1R	1982	4/93	C	36	24
	SATCOM 2R	1983	4/93	C	36	24
	K1	1/86	11/95	Ku	54	16
	K2	12/85	12/95	Ku	54	16
	SATCOM C1	11/90	2002	C	36	24
	SATCOM C3	10/92	2004	C	36	24
	SATCOM C4	9/92	2004	C	36	24
GTE	SPACENET 1	5/84	11/92	C	36	18
SPACENET				Ku	72	6
	SPACENET 2	11/84	11/92	C	36	18
				Ku	72	6
	SPACENET 3	4/88	4/98	C	36	18
				Ku	72	6
	SPACENET 4	4/91	2004	C	36	18
				Ku	72	6
	GSTAR 1	4/85	4/95	Ku	54	16
	GSTAR 2	3/86	2/96	Ku	54	16
	GSTAR 3	9/88	9/98	Ku	54	16
	GSTAR 4	11/90	2000	Ku	54	16
(CONTEL ASC)	ASC1	8/85	8/94	C	36	18
				Ku	72	6
HUGHES	GALAXY 1	6/83	1993	C	36	24
	GALAXY 2	9/83	1992	C	36	24
	GALAXY 3	1984	1994	C	36	24
	GALAXY 4	12/92	2004	C	36	24
				Ku	27	16
				Ku	54	8
	GALAXY 5	2/92	2004	C	36	24
	GALAXY 6	10/90	2000	C	36	24
	GALAXY 7	9/92	2004	C	36	24
				Ku	27	16
				Ku	54	8
	WESTAR 3	8/79	+ 8/86	C	36	12
	WESTAR 4	2/82	2/92	C	36	24
	WESTAR 5	6/82	6/92	C	36	24
	SBS4	8/84	9/94	Ku	43	10
	SBS5	1986	1998	Ku	43	14
	SBS6	10/90	2002	Ku	43	19
PANAMSAT	PAS1	6/88	1998	C	36	18
				Ku	72	6

+ Indicates satellite has exceeded design life.
Sources: DataPro August 90; DataPro August 91; DataPro September 91; Caprioglio 91; NASA

FIGURE 3-15
Cost of GEO Satellites

	C-BAND	KU-BAND
Satellite Development	$100 million	$160 – $180 million
Launch Vehicle (McDonnell-Douglas Delta 7920)	$45 million	$50 – $75 million
Launch Insurance (15–20% of Single Satellite)	$15 – $20 million	$24 – $36 million
TOTALS	$160 – $165 million	$234 – $291 million

Source: Caprioglio 91

3.5.4 Low Earth Orbit Satellite Technology

LEO satellite systems in general use many small, lightweight satellites in orbits less than 2000 km or 1250 miles. These systems, like GEO systems, are capable of providing voice, data, and video services operating in different frequency bands.

LEO satellite systems have a communications advantage over GEO systems in the elimination of transmission delay problems due to the lower orbit. These satellites can be made lighter and cheaper than GEO satellites, and provide for the ability to have small, lightweight, and inexpensive receive antennas on the ground.

Because LEO satellites are not geosynchronous, they move with respect to an observer on earth. Depending on the orbital altitude, a LEO satellite may be in view for as little as 20 minutes. Therefore, many satellites are required to provide continuous communications. While a GEO satellite mainly uses fuel only to maintain the precision of its stationkeeping, a LEO satellite also requires much fuel to maintain orbital altitude. The economic tradeoff between weight and cost results in a design life of about 5 years. The combination of large satellite constellations and frequent replacement requires inexpensive, timely, and reliable launch capabilities.

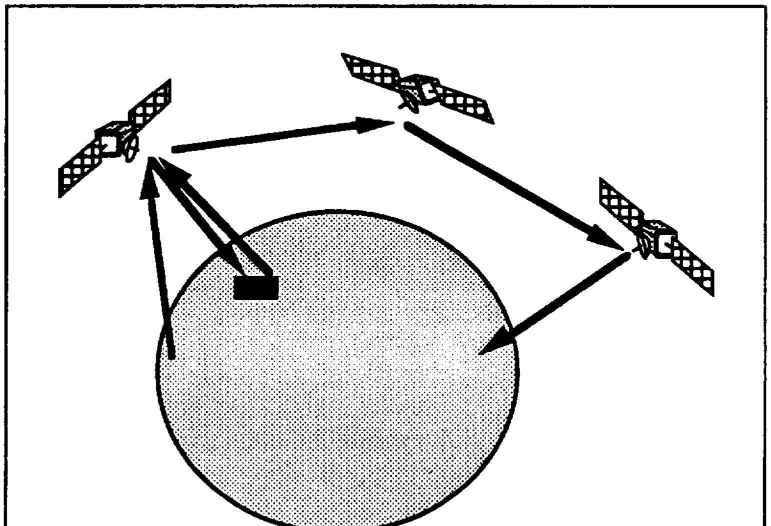
3.5.5 Low Earth Orbit Satellite Status and Plans

The main driver behind the interest in LEO satellite systems is interest in the cellular telephone, fax, and voice messaging businesses. Recent estimates are that, as the world's economy becomes global, the number of subscribers to cellular services could reach 100 million worldwide by the year 2000 (Foley October 1991, 25:23 – 28).

Unlike terrestrial cellular systems, in which users move though adjoining "cells" or areas of coverage, mobile satellite systems beam a moving cell onto the surface of the earth. LEO satellites could provide cellular phone service to a wide area without the delays associated with GEO systems (Data Pro August 1990).

Motorola Corporation announced in 1990 plans to develop a global cellular network called Iridium. Figure 3-16 depicts the Iridium system concept. This system will provide worldwide point-to-point communications. It will provide telephone service, facsimile, data transmission, global paging, radio-determination satellite services (RDSS), and global positioning services (GPS) for millions of users. The system as originally announced was to have 77 small satellites positioned in seven low-earth polar orbits of 413 nautical miles with 11 satellites in each plane. It has since been modified to have 66 satellites in six planes. (The system's name comes from the element iridium, which has 77 electrons circling the nucleus.) (Telecommunications 1990; Telephony 2 July 1990).

FIGURE 3-16
Iridium System Concept



Sources: Telephony 2 July 90; Telecommunications August 90

The choice of a LEO satellite to build the cellular network is based on two main issues. First, at these low altitudes, transmission power from an omni or low-gain antenna on the handset will be about one-thousandth of what is required to reach GEO satellites. This will make it possible to use a small handset or the type of small antenna found on cars for cellular service. (Telecommunications 1990; Telephony 2 July 1990)Second, because these satellites are not geostationary, Motorola expects to avoid some current regulatory procedures for satellite deployment and operation; these include the WARC's orbital assignments and the FCC's requirement for 2° spacing on orbit. The whole question of how to regulate LEO satellites is being reviewed extensively by the FCC at this time.

The following description is based on the original 77-satellite design. The details of the 66-satellite system are not available at this writing. Each satellite will operate cells that are approximately 372 nautical miles in diameter and can serve 110 simultaneous users. Signals from the handset to the satellite will operate at 1.5 GHz, are time-division multiple access (TDMA) coded, and use 8 kHz of bandwidth (4,800 bps) for voice. Data links will operate at 2,400 baud. Each satellite will have a design life of roughly 5 years (Foley). The constellation will have optimally phased polar orbits in which the satellites in the odd-numbered planes will be in phase with one another but halfway out of phase with those in the even-numbered planes. The elevation of 413 nautical miles was chosen to restrict the grazing angle between the subscriber and the nearest satellite to 10 to 90 degrees above the horizon. The 10-degree angle will occur only in the vicinity of the equator (Foley).

When a phone is turned on, a satellite will receive the signal and register the user at the nearest local gateway. A caller using the system simply dials the unique number of the person being called. Routing will be handled on earth via the gateway station. The gateway instructs the satellite as to how to complete the call. This satellite then transfers the call to another satellite along with the switching information. Eventually the appropriate satellite completes the call to the person being called. The gateway determines which satellite is able to complete the call, because it knows the location of each user and the orbital position of the satellites with respect to time of day, and sends the appropriate control signals to the satellite. Control signals from the satellite to the gateway will operate at 20 GHz; initially there will be 20 gateways. (Telecommunications 1990; Telephony 2 July 1990)

Motorola emphasizes that the system is designed to complement and not supplant existing and planned cellular networks for high-density areas, such as the Groupe Speciale Mobiles (GSM)-based, pan-European digital cellular system. The system is designed to operate with a handset similar to Motorola's existing Dyna-Tac product. The intention is to equip the eventual handset with the capacity to conform to both local standards (e.g., GSM, PCN) and Iridium. Since GSM and Iridium are both TDMA-based, some overlap in component functionality can be expected. Because of this, many people have speculated that Iridium will be viable only in the extreme rural areas and the Third World, maintaining that there are already viable terrestrial systems that are very cost effective and many more are being planned in Europe. (Telecommunications 1990; Telephony 2 July 1990)

Other LEO systems are planned to operate on premises similar to Iridium. Intelsat has announced that it plans to put in place by the year 2000 a global cellular phone system using LEO satellites for roughly half the cost of Motorola's system. Intelsat's system, called Project 21, will use a combination of GEO, elliptical, and LEO satellites to implement the system. Project 21 features include handsets for less than $1,000 and call delivery at a cost of $1 a minute. (Washington Technology December 1991; Computergram International September 1991)

3.5.6 Low Earth Orbit Satellite Capacity

Total capacity of the Iridium system will be 5 million subscribers, and it will be able to handle 10 times as many calls as today's communications satellites (Foley).

The Iridium subscriber base has been forecasted for the years 2001 and 2006, which are years 5 and 10 of operation. The worldwide total number of subscribers is estimated to be 1.8 million in 2001 and 2.8 million in 2006. Iridium is being marketed as a business, government, and personal communications system.

3.5.7 Low Earth Orbit Satellite Cost to Install

The original Iridium system was expected to cost about $3.2 billion to design and implement and be operational by 1997, assuming Motorola can overcome any technical problems and regulatory issues. Motorola plans to launch two demonstration satellites in 1992 and to begin implementation of the full system in 1994. The intention is to keep the system an open architecture to promote competition and reduce costs of handsets until individuals can afford them. Motorola has formed Iridium Inc., headquartered in Washington, D.C., to handle the sale of shares, marketing, and development of the Iridium system. Motorola signed letters of mutual understanding in August 1991 to use Lockheed Commercial Space Co. to develop the space bus and Raytheon Co. Equipment Division to develop the main mission antennas for the Iridium system.

3.6 VERY SMALL APERTURE TERMINAL TECHNOLOGY

High-powered Ku-band satellites, coupled with earth stations of ever-decreasing dimensions and backed by wide general acceptance of the versatility and cost-effectiveness of satellites, form the basis for most VSAT systems (Data Pro August 1990).

The VSAT network services market is clearly beyond its early difficulties. Frost & Sullivan predicted that the market for VSAT earth stations will reach $246 million by 1993, an increase from $117 million in 1989, caused mainly by a changing perception of the technology resulting from the industry's demonstrated success and its consolidation (Data Pro August 1990).

The VSAT market is global and, as costs for both the ground and space segments continue to decline, previous thresholds of cost-effectiveness are being lowered. As recently as 1988, the break-even point for a VSAT hub and spoke network was in the range of 100 or more remote terminals. By 1990, initial deployments of hub and spoke networks with as few as 10 remote locations were economical. In fact, for specialized applications, point-to-point networks using VSAT equipment are feasible (Data Pro August 1990).

3.7 MICROWAVE RADIO

Microwave radio technology is well suited for point-to-point use over long and short distances. Radio's use in long-haul communications, especially telephony, is declining. The largest area of increased use for radio technology appears to be in the area of microwave LANs and cellular communications.

This section discusses the two primary areas of use for radio technology: long haul and short haul. It outlines each technology, including its history and its future.

3.7.1 Long-Haul Technology Assessment and History

Long-haul microwave refers to transmissions of more than 30 miles. Long-haul microwave was the principal transmission medium for the long-distance telephone network during the 1950s through the mid-1980s. During the 1950's, transcontinental microwave systems were routinely handling more than 2,000 voice channels on "hops" averaging 25 miles. Microwave was especially popular in rough terrain where pole-and-wire lines would be costly and impractical. During the 1960's, corporations such as railroads, utilities, and oil companies began to build their own microwave systems. Microwave systems offered private companies significant advantages over the PSN. Microwave transmission costs were low enough for corporations to justify developing their own systems.

During the 1980's, microwave technology was further enhanced by the development of digital microwave. This helped eliminate some of the problems associated with analog transmissions. This helped microwave technology adapt to the business needs of corporations, specifically data transmissions. However, long-haul transmissions were being challenged by old and new technologies that have fewer inherent problems than microwave. Satellites and fiber optics were taking market share away from long-haul microwave technologies.

3.7.2 Long-Haul Status and Plans

Fiber optics offers almost infinite bandwidth and transmits data with virtually no errors. Fiber began to dominate the long-haul telecommunications traffic during the 1980's. The microwave market not addressed by fiber optics was being challenged by satellites. For example, during the 1980's much of the cable and broadcast TV market that had used microwave systems migrated to satellite transmission. The increased use of fiber optics and satellites has drastically reduced the use of long-haul microwave transmissions during the 1980's. There are still microwave systems in use, but most applications historically based on microwave technology have been or will be converted to other transmission media.

The future of long-haul microwave systems is stable with a possible decrease in market share. Some microwave systems are maintained as backup to fiber, and others are still used in remote areas. There have been some advances in microwave technology during the 1990's, including bandwidth compression techniques and Multiple Address Systems, but fiber optics is the future of long haul transmissions. Consequently, long-haul microwave will not demonstrate any growth in the near future.

3.7.3 Short-Haul Technology

Short-haul microwave consists of transmissions of fewer than 20 miles. Short-haul microwave became popular in the late 1970's when the Federal Communications Commission (FCC) started deregulating the airwaves, thus making it easier to get FCC licenses. Companies wanted to control telecommunication costs and availability. Microwave offered companies reduced telephone billing, simple installation, and larger amounts of bandwidth at a reasonable cost. Furthermore, there was a move toward digital connectivity. Long-distance networks had already moved to digital, and electronic switching was also digital; there needed to be short-haul connectivity between these points. Short-haul microwave technology fit this niche market very well. Through the 1980's and into the 1990's, new applications have been developed to take advantage of microwave's inherent advantages.

3.7.4 Short-Haul Status and Plans

There are many applications for short-haul microwave radio. Short-haul microwave is being used in public, private, cellular networks, and also for LAN interconnection. The market for short-haul microwave is expanding. PCNs, motor vehicles, and highway automation are just some of the potential new markets for microwave. In contrast to long-haul microwave, short-haul transmission offers competitive advantages over fiber optics in several markets. In locations where installing fiber is not cost effective, microwave offers easy-to-install digital connectivity. Microwave has also proven useful in restoration. For example, after the Hinsdale, Illinois, fire in 1988, microwave was used to restore links to the long-distance network.

The future of short-haul microwave technology looks good. Several new technologies, including cellular and PCN, will spark new growth in the microwave industry. Short-haul microwave serves as a complement to fiber optics and is therefore not in direct competition. Short-haul microwave technology should continue to grow with the advent of new applications that fit into its market niche.

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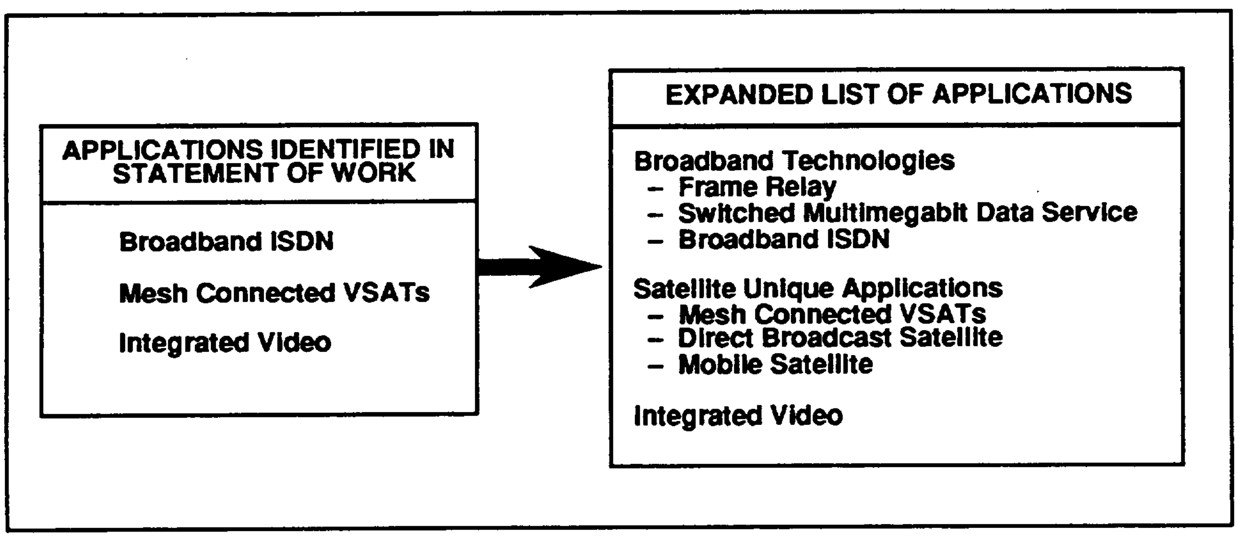
4.0 APPLICATIONS

This section describes the applications that are expected to dominate the use of the telecommunications infrastructure through the year 2011. Four major application areas are described: broadband technologies, fixed satellite systems, integrated video, and mobile wireless systems. A brief overview of the methodology used in examining dominant applications and details describing the status, plans, deployment coverage, costs, and traffic estimates for each application area are provided.

4.1 METHODOLOGY

As illustrated in figure 4-1, four major application areas are described in this report. The three specific applications identified by NASA (i.e., BISDN, Mesh VSAT, and integrated video) have been included in more generally defined application areas to facilitate the description of related technologies and trends. Additionally, NASA's list of applications has been expanded to include direct broadcast satellite and mobile wireless systems.

FIGURE 4-1
Subtask 3 Summary



Our approach to this effort focuses on analyzing factors of supply and demand for each application area. A supply-side consensus is developed for each application based on an analysis of information obtained from research and development groups, equipment manufacturers, standards bodies, carriers, and regulatory groups. In some cases, internal Booz·Allen experts were used to reconcile conflicting information and views to reach a consensus. Demand for each application area is analyzed by reviewing the current uses of telecommunications within an industry segment, identifying long-term business trends, and projecting future service requirements. Demand projections that have been developed by service providers and forecasters are also considered as part of this analysis. The data presented in this section are further analyzed in sections 5.0 and 6.0.

4.2 BROADBAND TECHNOLOGIES

Emerging high-speed data transmission requirements, a changing ratio of voice to data traffic, and the emergence of video traffic are spurring the development of advanced technologies to support the anticipated demand for new communications services. Common to all of these new services is the rapid development of efficient packet technology as the basis for new network architectures to support these services. Fast-packet (cell/frame) technology is replacing time-division multiplexing and traditional X.25 architectures because of the benefits it brings to rapidly growing end-user applications such as LAN interconnection. Specifically, these benefits include efficiency, improved response times, transparency, and resiliency.

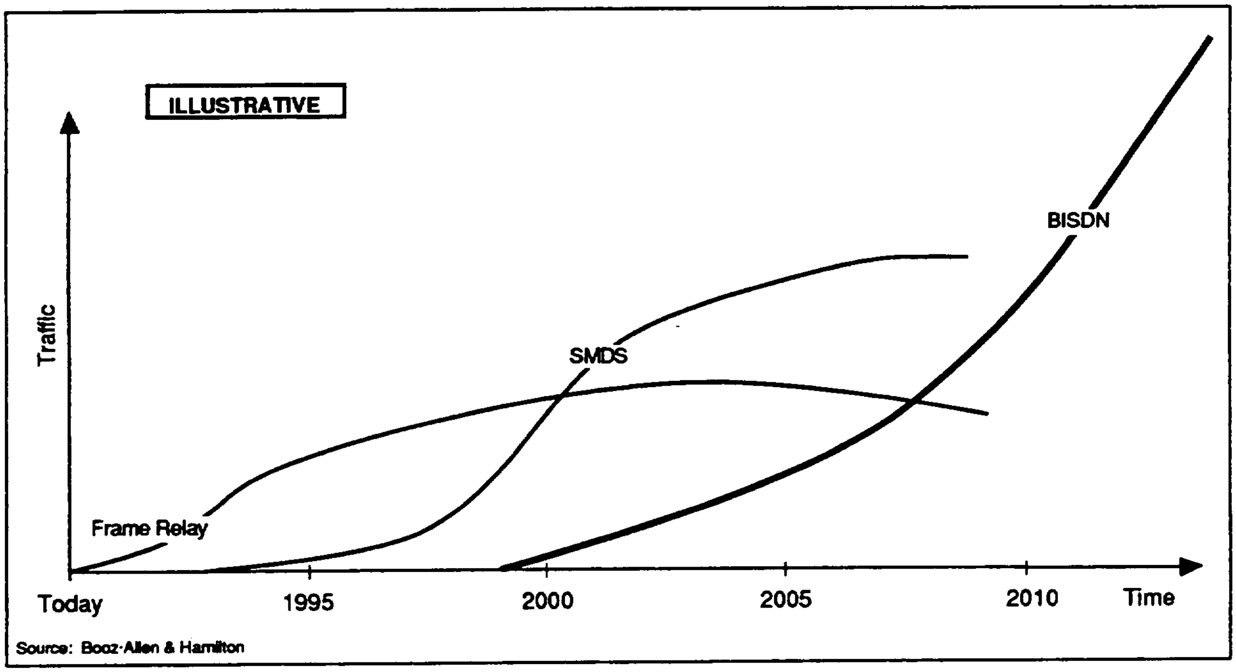
Three emerging services are included within the broadband technologies application area: frame relay, SMDS, and BISDN. Figure 4-2 illustrates the basic technical characteristics of each of these applications. Frame relay and SMDS, although available today, have been included in this study because their deployment and user acceptance over the next several years will serve as indicators of the demand for broadband services. Additionally, these service offerings are generally viewed as a carrier's first attempt to market broadband type services. As illustrated in figure 4-3, frame relay and SMDS will serve as precursors to BISDN in that frame relay will eventually migrate onto BISDN as a bearer service, and SMDS will evolve as an access technology for BISDN. Frame relay, SMDS, and BISDN are presented in the following sections.

FIGURE 4-2
Broadband Services Characteristics

Service / Characteristic	Frame Relay	SMDS	BISDN
Transmission Speed	Up to 2.048 Mb/s	1.544 Mb/s – 45 Mb/s	≥50 Mb/s
Applications	Data	Data	Voice Video Data
Addressing	Local/Virtual	Global	Global
Packet Length	Variable	Fixed	Fixed
Access Interface	Frame (Lap D)	Cell (IEEE 802.6)	Cell (ATM)

Source: Booz-Allen & Hamilton

FIGURE 4-3
Broadband Service Life Cycles



4.2.1 Frame Relay

Frame relay is an emerging data access standard that is being used to interface private network backbone switches and is also being offered as a carrier-based service. It is designed to support LAN interconnection and existing host computer environments such as SNA. Frame relay, with its superior performance as compared to traditional packet networks, is ideally suited to support the rapidly growing demand for high-speed data transmission required for LAN interconnection.

Few communications technologies have matured as quickly as frame relay, which was originally proposed as an additional bearer service for ISDN. Since its initial proposal, significant effort has been spent on standardizing frame relay as a stand-alone technical solution, while maintaining its compatibility with ISDN. Rapid development of frame relay was in part possible by taking advantage of work that had been done earlier on the transmission of bursty data by the now defunct ANSI T1D1 working group and other related CCITT ISDN B channel work.

Frame relay services can be broken down into two general categories that share common interface standards: Frame Relay and ISDN Frame Relay. Frame relay services available today support data transmission over private virtual circuits (PVCs) that allow communications among members of a closed user group. ISDN frame relay, when available, will also provide a switched virtual circuit capability via ISDN significantly expanding the utility of this technology. Public and private networks providing frame relay are identical in the use of frame relay protocols, varying only in areas such as ownership, location, and management of equipment.

Traditionally, full-mesh physical connectivity has been required for linking LANs and WANs. This configuration minimizes transmission latencies by reducing the number of tandem links and ensures the availability of alternative transmission routes during a link failure. Using frame relay, full-mesh connectivity can be provided logically, over a single transmission backbone, rather than requiring multiple physical connections. The key advantage of this alternative architecture is the significant reduction in overall network costs through the reduction of the number of required dedicated links.

4.2.1.1 Status

Standards

A diverse group of organizations support the implementation of frame relay. Supporters include the more than 100 members of the Frame Relay Implementor's Forum (founded by Cisco, DEC, StrataCom, and Northern Telecom), large end-user organizations, government agencies, manufacturers, public carriers, and numerous domestic and international standards bodies. A summary of current frame relay standard-setting activity is provided in figure 4-4.

FIGURE 4-4
Frame Relay Related Standards

ORGANIZATION	STANDARD	DESCRIPTION
ANSI	T1.606-1990	Integrated Services Digital Network (ISDN)—Frame Relaying Bearer Service Architectural Framework and Service Description for Frame Relaying Bearer Service
ANSI	T1S1/90-175R4	Addendum to T1.606
ANSI	T1S1/88-2242	Frame Relay Bearer Service—Architectural Framework and Service Descriptio
ANSI	T1S1/90-213 (T1.6ca)	DSS1—Core Aspects of Frame Protocol for Use With Frame Relay Bearer Service
ANSI	T1S1/90-213 (T1.6fr)	DSS1 — Signaling Specification for Frame Relay Bearer Service
CCITT	I.122	Framework for Providing Additional Packet Mode Bearer Services
CCITT	I.431	Primary (1544,2048 kb/s) ISDN Interface
CCITT	Q.922	ISDN Data Link Layer Specification for Frame Mode Bearer Service
CCITT	Q.931	ISDN Network Protocol
CCITT	Q.933	ISDN Signaling Specification for Frame Mode Bearer Services

Source: Booz·Allen & Hamilton

Equipment Manufacturers

The rapid standardization of frame relay and the growing number of service providers announcing plans to offer these services have resulted in equipment manufacturers' accelerating product development schedules. Currently, more than 60 manufacturers have introduced frame relay or frame relay compatible equipment for both private and public networking applications (Finn 3 February 1992, 31-37). Some existing equipment, such as routers and concentrators, are being modified or retrofitted to support frame relay and broaden product functionality, while other equipment, such as switches, are being redesigned with entirely new architectures. Products that have been introduced to date are designed to support frame relay PVCs, with future product development efforts to focus on supporting switched virtual circuits (SVCs). Overall, the large number of vendors supporting frame relay and the diverse nature of their products are very strong indications as to the industry's assessment of the frame relay service market's size.

Service Providers

Although some frame relay products and services are available today, users are for the most part still in the testing mode. Operators of private networks tend to be upgrading small portions of their networks and experimenting with the use of frame relay technology. Likewise, the number of users that are currently buying carrier-based services is relatively small. To date, approximately 30 companies are using frame relay services provided by WilTel, CompuServe or BT North America, which are the three service providers with the largest market share (Gareiss 27 January 1992, 43). Customers are only using frame relay services for a small fraction of their traffic while they continue to evaluate its performance before larger scale implementation.

4.2.1.2 Plans. As a result of growing user interest in and demand for frame relay services, the number of service providers planning to offer these services has grown from 3 to 19 in the past year. As illustrated in figure 4-5, a mix of interexchange carriers, value-added-network providers, and local exchange carriers have announced plans to provide frame relay services and they are at varying stages of their product rollouts (Gareiss 27 January 1992; Gareiss 20 April 1992; Thyfault 1992, 46). Although Sprint, BT North America Inc., and Compuserve Inc. were the first companies to announce their plans to offer frame relay services, WilTel was actually the first carrier to roll out a service beginning in March 1991.

Most recently, LECs have announced plans to offer frame relay services. RBOCs and large independent telephone companies such as GTE Telephone Operations had originally planned to provide SMDS as their primary data networking service for the future, but are now also planning to offer frame relay. Officials of a number of RBOCs cited the increasing availability of frame relay equipment and the interLATA carriers' deployment of frame relay as principal reasons for their reconsidering this service (Killette 2 March 1992, 1). Nynex was the first RBOC to file a tariff for its frame relay service in February of 1992, and is currently offering 56 kb/s and 1.544 Mb/s access rates.

Frame relay will potentially compete with private line services now offered by carriers. As a result, companies such as Sprint that have a small private line market share have the most to gain by offering frame relay and have actively pursued this market. AT&T and MCI, which have larger shares of the private line market, are approaching frame relay more cautiously, hoping to minimize loss of their revenues. In 1991, AT&T accounted for 52 percent and 40 percent of the analog and digital private line markets, respectively. In 1991, MCI held 11.2 percent and 17.5 percent of the analog and digital private line markets, respectively (Wallace, 13 January 1992, 1).

4.2.1.3 Deployment Coverage. Frame relay deployment in private and public networks will be driven by factors of supply and demand. Factors of supply primarily relate to the uniform application of frame relay standards to equipment by equipment manufacturers and network designers to allow interoperability of systems. Factors of demand include the future requirement

FIGURE 4-5
Frame Relay Service Status

COMPANY	STATUS AS OF JULY 1992
LECs	
Ameritech	Developing tariff; to announce plans for user trials soon
Bell Atlantic	Has not developed specific plan
BellSouth	Has not developed specific plan; deployment would be no sooner than early next year
GTE	Plans to do internal technology tests in 2nd quarter; has tentatively slated user trials for 3rd or 4th quarter of 1992
NYNEX	Filed tariff for April rollout in New York; expects to deploy in Massachusetts in mid-1992
Pacific Telesis	Has had user trials underway since December 1991
Southwestern Bell	Testing wide area network interconnections; working to select a switch vendor; preparing tariff
US West	Preparing tariff; plans June 1992 service rollout in 15 cities, etc.
IECs	
AT&T	Service currently available; initially offered 2d quarter 1992
MCI	Service currently available; initially offered 2d quarter 1992
Sprint	Service currently available; initially offered 4th quarter 1991
Others	
BT North America	Service initially available 3d quarter 1991
Cable & Wireless North America	Service initially available 2d quarter 1992
CompuServe	Service initially available 4th quarter 1991
G.E. Information Services	Unannounced
Graphnet Inc.	Service initially available 3d quarter 1991
Infonet	Service initially available 3d quarter 1992
Westinghouse Communications	Service initially available 2d quarter 1992
WilTel	Service initially available 1st quarter 1991

Sources: Gareiss 27 January 1992; Gareiss 20 April 1992; Thytault 1992 for high-speed (in the range of 56 kb/s to 1.544 Mb/s) LAN-to-LAN data interconnection. Each of these factors is discussed in the following paragraphs.

Factors of Supply

Although standards for frame relay exist today, their interpretation and implementation vary significantly among vendors and carriers. Today, interoperability between customer premises equipment, such as routers, and public or private switches is generally ensured given vendor compliance with existing standards. However, standards for interoperability among network switches is not as well defined and has resulted in single vendor and single carrier networks. Additionally, the way carriers implement CCITT Q.922, which defines the core aspects of frame relay, significantly varies and further hampers efforts towards interoperability of networks (Finn 3 February 1992, 31-37).

Carriers have established frame relay backbones through their respective networks. Because no carriers have interconnected their frame relay networks, users are limited to selecting a single carrier. This limitation prevents a user from sending traffic from a site served by one carrier's frame relay service to a site served by another's. Additionally, customers must connect directly to an IEC for inter-LATA service.

Congestion management schemes, which prevent network switches from being overwhelmed by more traffic than they can process, are not yet fully resolved. While CCITT frame relay standards identify several methods for congestion avoidance and recovery, none is mandatory. Additionally, due to variations in interpretation and implementation of these standards, even carriers attempting to implement a common congestion management approach are unable to interoperate their systems. Several service providers including AT&T, MCI, WilTel, and CompuServe have announced plans to offer customers a simple network management protocol-based management terminal to monitor traffic flow and mitigate congestion problems. This problem is expected to be resolved by early 1993.

Sprint leads other carriers in frame relay deployment by using 12 TP4900 packet switches. WilTel has deployed 10 IPX multiplexers manufactured by Stratacom, and AT&T, which is also using the Stratacom system, has not released the number of switches it plans to deploy (Killette 2 March 1992, 1). Switch deployment is not a major issue for users because carriers are planning to initially backhaul user traffic to the closest frame relay switch at no cost, but it is an indication of the commitment on the part of carriers to support these services. All three of these carriers plan to deploy additional switches based on customer demand.

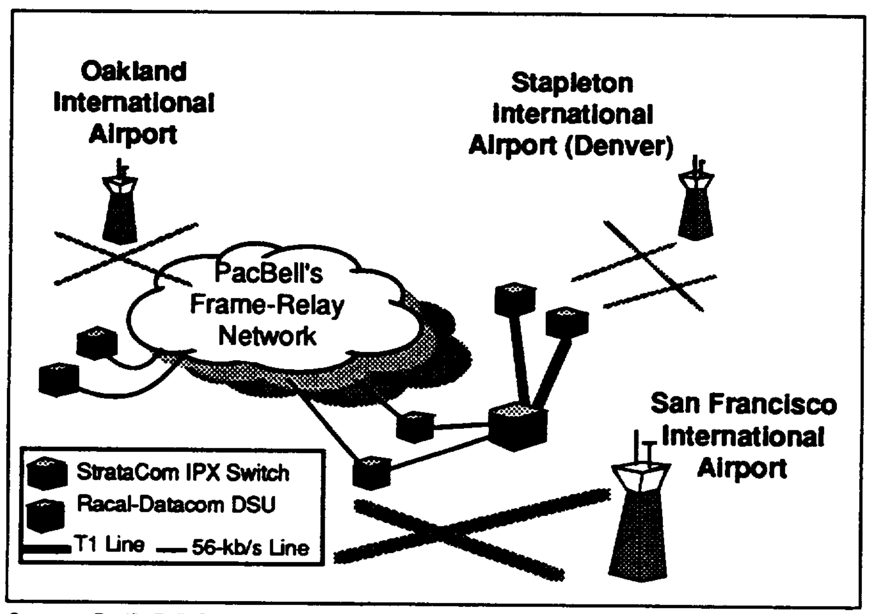
The most likely scenario for the deployment of frame relay over the next 5 years is a hybrid approach in which traffic will pass between private and public networks. Hybrid networks will reduce leased-line costs for users by allowing them to connect their private networks to public networks by using packetized facilities such as Asnchronous Transfer Mode (ATM). Also, the hybrid approach will provide users with significantly greater flexibility in configuring and reconfiguring their networks and this will further reduce costs.

Pacific Bell is now conducting the first field trial of a hybrid network with Covia, a company that operates travel reservation systems for United Airlines and six other international airlines. In this test, travel reservation data will be passed between Covia's private frame relay network and Pacific Bell's frame relay network. As illustrated in figure 4-6, Covia is sending data between a token-ring LAN at a Denver site at the Stapleton International Airport and its offices at San Francisco International Airport using its own network (Schultz 6 April 1992, 1). Data transmission between San Francisco and Oakland is accomplished using Pacific Bell's network. Field trials of this type are expected to increase, which will demonstrate the advantages and the speed of acceptance of hybrid network frame relay deployment.

Factors of Demand

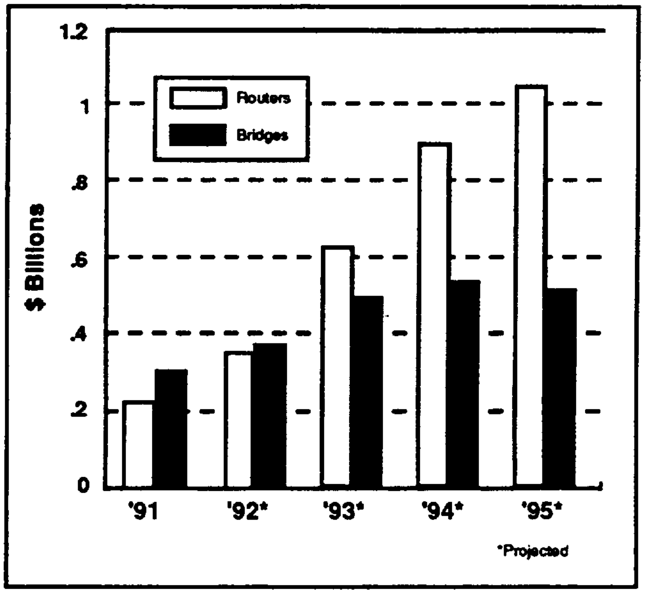
The demand for frame relay services, which will determine the extent to which frame relay networks will be deployed, will be primarily driven by the growing need for high-speed LAN-to-LAN interconnects. The importance of internetworking to users has been reflected by the sharp increase in demand for interconnect services and hardware. CIMI Corporation, a market research firm, found that carrier revenues associated with LAN interconnection exceeded $900 million in 1991 and are expected to grow to nearly $2.5 billion by 1995 (Appleby and Stahl 1992, 1). The sale of LAN interconnect equipment continues to rapidly grow and is expected to continue growing through 1995 as illustrated in figure 4-7 (Appleby and Stahl 1992, 68).

FIGURE 4-6
Frame Relay Airline Reservation Application



Sources: Pacific Bell; Communications Week

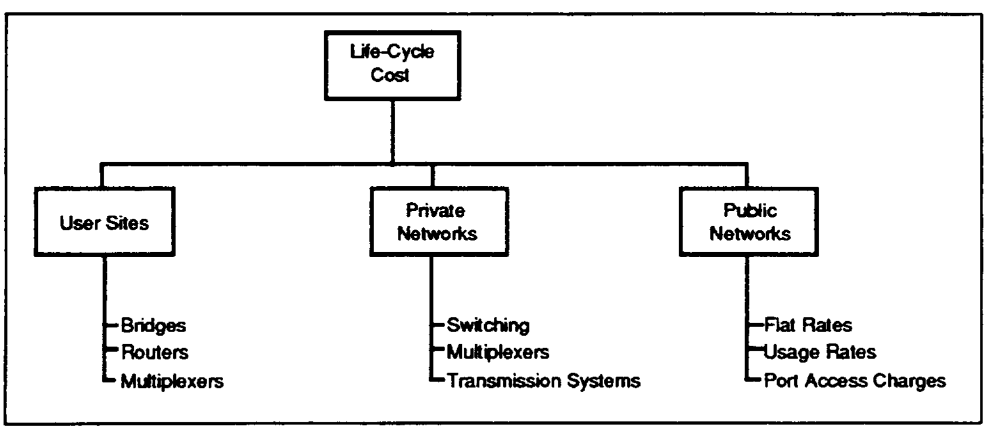
FIGURE 4-7
LAN Interconnect Equipment Sales



Source: CIMI Corp Cited in Appleby and Stahl 1992

4.2.1.4 Cost. As illustrated in figure 4-8, the cost of frame relay can be analyzed based on the type of network implementation employed: private or public. Hybrid networks represent a combination of private and public networks. Life-cycle cost for each implementation will depend on whether equipment is purchased or services are leased. Unique equipment for frame relay networks generally consists of end-user or customer premises equipment for network access, such as routers, and backbone packet switching devices. For both of these types of frame relay network elements, the technology required is a variation of the same technology used for manufacturing

FIGURE 4-8
Frame Relay Cost Breakdown



other types of packet-based networks. In most cases, manufacturers are offering frame relay modules that can be added to existing routers to provide additional functionality, and upgrades to switching platforms to support frame relay.

Figure 4-9 provides pricing for a representative sample of commercially available frame relay router and switching hardware for private and public network applications. In the case of routers, the large number of manufacturers offering technically similar products will result in competitive economic pressure to reduce prices by 25 percent by 1995 before the market stabilizes. In the case of network switches, the small number of manufacturers operating in a relatively captive market will result in less than a 5 percent reduction in product costs by 1995 before the market stabilizes.

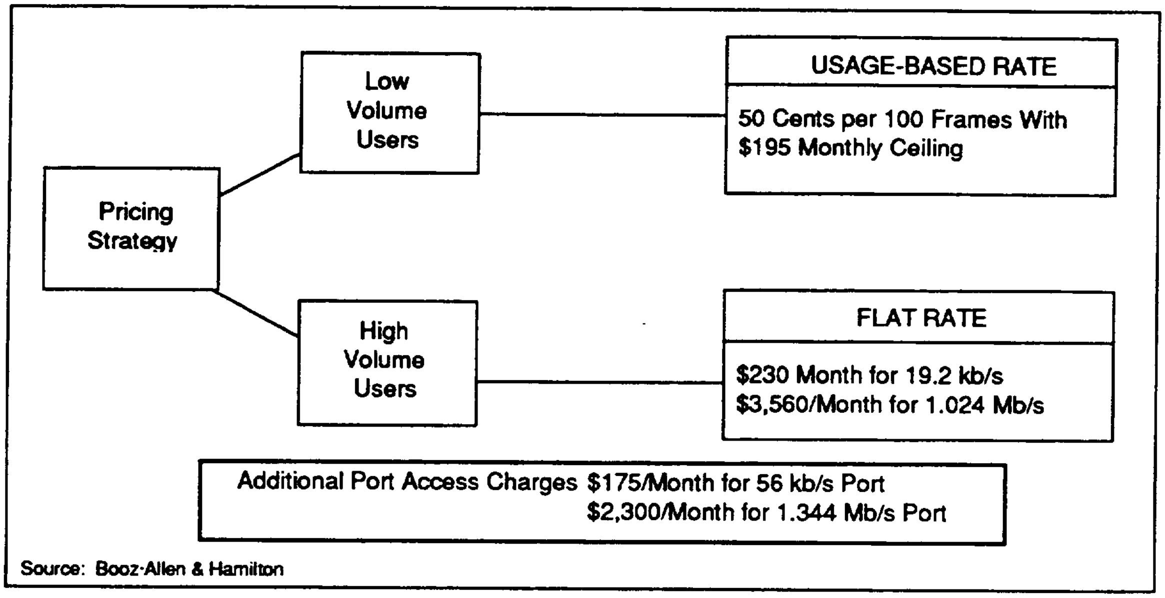
FIGURE 4-9
Frame Relay Equipment Pricing

COMPANY	PRODUCT	PRODUCT TYPE	PRICE
AT&T Network Systems	BNS-1000	Switch	$32,600
ASCOM Timeplex	Frame Server	Access and Switch	$13,500 (4 Ports) to $25,500 (12 Ports)
Cisco Systems	MGS Routers	Access	$750 and up
Frame Relay Technologies	Frame, MUX 100	Access and MUX	$11,700 and up
METRIX	# 1 – ISS	Switch and MUX	$10,000 and up
Newbridge Networks	3600 FRS 8100 FRR 8230 Little Bridge	Switch Access Access	$7,500 $6,500 $1,700
Northern Telecom	DPN-100	Switch	$70,000
STRATACOM	IPX	Switch and MUX	$14,000

Source: Manufacturers' literature

Since the first carrier, WilTel, began offering frame relay services in March 1991, the frame relay market has become extremely competitive with significant variation in service pricing. Figure 4-10 illustrates a typical frame relay service pricing strategy. Typically, service providers are offering pricing options geared to attract both low- and high-volume users. Both WilTel and Sprint have already undergone a second revision to their pricing structure while AT&T and MCI are just rolling out their service offerings. We expect that it will probably take carriers until the second half of 1993 before long-term pricing structure and levels are determined.

FIGURE 4-10
Representative Frame Relay Service Pricing

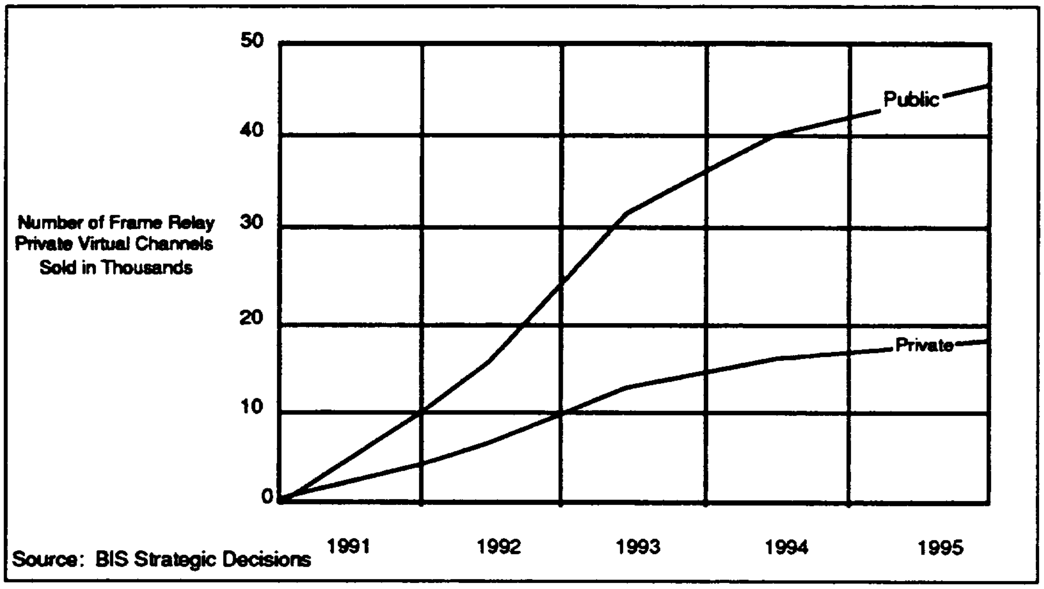


4.2.1.5 Traffic. Frame relay applications will account for a significant amount of data transmission traffic until cell-based transmission technology such as ATM becomes widely available. We expect to see continued rapid growth of frame relay traffic on stand-alone systems through the year 2000, at which time some of this traffic will migrate onto BISDN as an ISDN bearer service and some will be supplanted by ATM technology for high-bandwidth applications.

The number of computing devices linked by communications will continue to grow rapidly, providing a niche market for frame relay. In 1991, approximately 36,000 communicating data centers, 80,000 communicating departmental computers, and 113,000 communicating LANs existed. By 1995, there will be 58,000 communicating data centers, 156,000 communicating departmental computers, and 333,000 communicating LANs (Zerbeic 1992, 36). In the future, we expect to see a growing number of work stations and data centers linked directly via public network-based frame relay SVCs.

Frame relay traffic will be carried on both private and public networks. As illustrated in figure 4-11, the public frame relay market will be about twice the size of the private market (BIS Strategic Decisions). Current projections are for the public market to reach 42,000 PVCs by the end of 1995, compared with 21,000 PVCs for private use. Growth rates are projected to be most rapid between 1992 and 1993, with overall traffic levels peaking in the 1999 timeframe. Note that these traffic projections are in terms of virtual channels, which could be operating at speeds from 56 kb/s up to 1.544 Mb/s. Therefore, these projections do not agree with the values presented in figure 4-12, although the trends are the same.

FIGURE 4-11
Frame Relay Market Forecasts



Frame relay traffic projections through the year 2011 are provided in figure 4-12. These projections are based on anticipated traffic levels developed in section 2.0, extrapolation of current frame relay market trends, and analyses of future technology availability and substitution. As indicated in the figure, frame relay traffic will include e-mail, terminal operations, EFT, and EDI and will primarily be generated through increased LAN-to-LAN interconnection. Based on Booz·Allen estimates, frame relay usage will grow from very low levels in 1991 (less than 1 percent) to a peak in 1996 of potentially 40 percent of total data traffic. After 1996, frame relay traffic growth will level off and then fall as other high-speed technologies become available. As BISDN becomes available to business users on a widespread basis, a low level of frame relay applications will continue to be used, but most of the traffic will migrate to BISDN.

4.2.2 Switched Multimegabit Data Service

SMDS is a carrier service concept for connectionless data service that has been developed by Bellcore. It is intended to provide a high-speed, central office-based metropolitan area network (MAN) that will give users an alternative to private systems. The service is based on the IEEE 802.6 MAN protocol and has been designed for easy migration to an ATM environment.

Although IEEE 802.6 was designed for a multi-access environment, SMDS is being offered as a point-to-point star access service via a public switch. As illustrated in figure 4-13, access will be offered at both the DS-1 and DS-3 rates. While IEEE 802.6 supports isochronous capabilities, SMDS does not currently support voice, video, or traditional data (i.e., X.25) transmission.

FIGURE 4-12
Frame Relay Traffic Projections

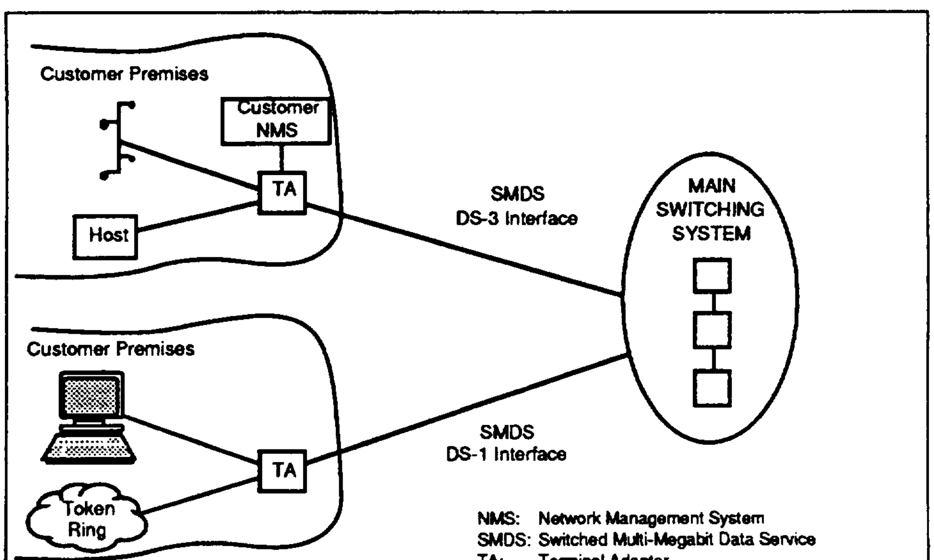
	DS0 Units	Busy Hour DS0s 1991	1996	2001	2006	2011
Voice						
MTS (Business)	DS0s (10^6)	-	-	-	-	-
MTS (Residential)	DS0s (10^6)	-	-	-	-	-
Private Lines	DS0s (10^6)	-	-	-	-	-
800	DS0s (10^6)	-	-	-	-	-
900	DS0s (10^6)	-	-	-	-	-
Private Networks	DS0s (10^6)	-	-	-	-	-
Data						
Facsimile	DS0s (10^3)	3.1	130	18.0	2.2	1.45
E-Mail	DS0s (10^3)	0	0.21	5.8	14.0	15.0
Terminal Operations	DS0s (10^3)	0.082	3.0	3.6	2.6	1.9
On-Line Info. Services	DS0s	-	-	-	-	-
EFT	DS0s (10^3)	0.0190	1.20	1.00	0.59	0.31
EDI	DS0s (10^3)	0.0060	0.28	0.28	0.160	0.083
Video						
Network Broadcast	DS0s (10^3)	-	-	-	-	-
Cable TV	DS0s (10^3)	-	-	-	-	-
Educational TV	DS0s (10^3)	-	-	-	-	-
Business TV	DS0s (10^3)	-	-	-	-	-
Viewer Choice TV	DS0s (10^3)	-	-	-	-	-
		0.02	0.4	0.2	0.1	0.05

Source: Booz-Allen Analysis

Traffic Allocation Factor*

* Traffic allocation factors are the fractions of total traffic that represent potential frame relay traffic

FIGURE 4-13
SMDS



Source: Booz-Allen & Hamilton

The distinguishing characteristic of SMDS is that it provides connectionless data transfer. By definition, this type of service allows the connection between users to be established and disconnected at the same time that information is transferred. The primary application for connectionless data transfer is for high-speed (T1 or T3) LAN interconnect type service. While frame relay can support both connection-oriented and connectionless data transfer at lower rates, SMDS is more narrowly focused to support only connectionless data transfer at significantly higher rates. SMDS can be viewed as one access protocol to a future cell relay-based network that will support a wider range of services.

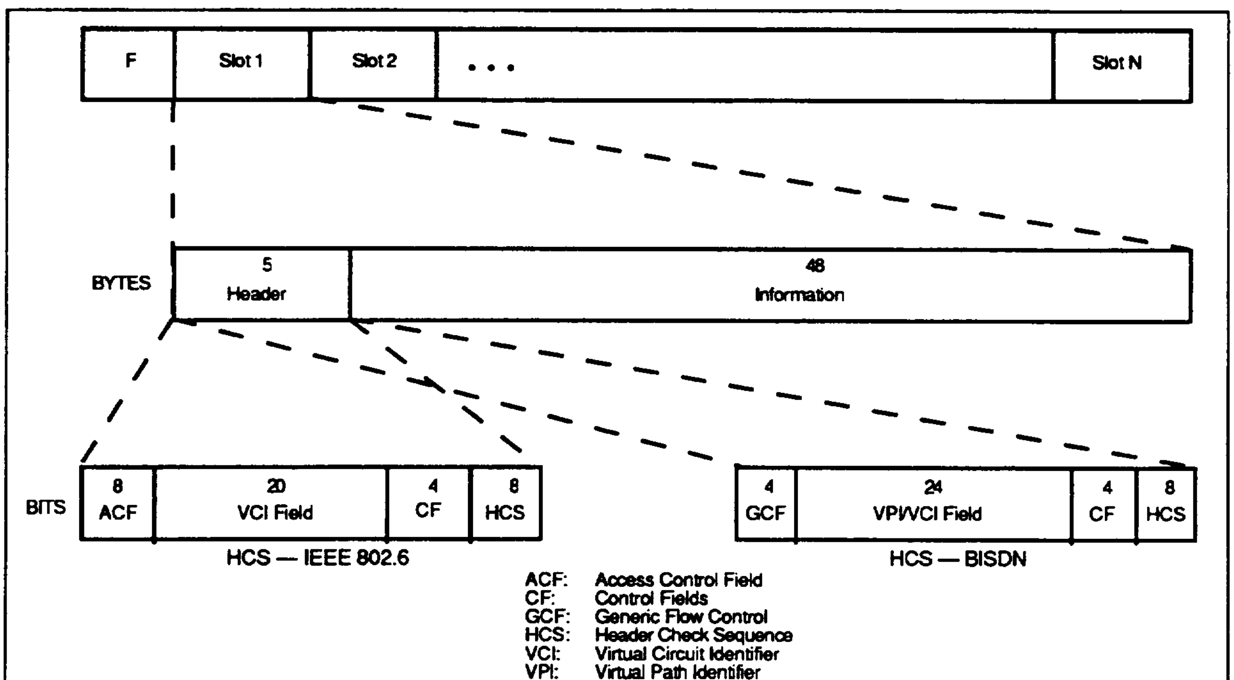
Figure 4-14 illustrates the basic cell structures defined for IEEE 802.6 and ATM-based BISDN. Although some differences exist in the header format, overall cell size and format are sufficiently similar to allow future compatibility. A common set of interfaces for IEEE 802.6 and ATM-based networks will facilitate the use of SMDS as an access means for BISDN.

4.2.2.1 Status

Standards

As illustrated in figure 4-15, SMDS is defined by a set of service specifications that have been developed and released by Bellcore. The protocol for SMDS is based on IEEE 802.6, which was finalized by standards bodies in September 1988. Bellcore's approach to developing SMDS specifications has been to develop and release those core specifications needed for carriers to offer a basic SMDS service with specifications defining service enhancements to follow.

FIGURE 4-14
Broadband Service Cell Structures



Source: IEEE Communications Magazine

FIGURE 4-15
SMDS Specifications

AREA	STANDARD/ADVISORY
Protocol	IEEE 802.6
Service Specifications (BELLCORE)	TA – TSY – 000772
	TS – TSY — 000773
	TA – TSY — 000774
	TA – TSY — 000775

Source: Bellcore technical documentation

In January 1992, Bellcore released specifications defining the interfaces required for LECs to interconnect their SMDS services with other domestic and international carrier networks. The proposed Exchange Access SMDS (XA-SMDS) specification is designed to allow an end user's local SMDS features to be extended transparently to interexchange SMDS networks. The target date for implementation of XA-SMDS, which will significantly expand the utility of this service, is late 1992 (Finn Killette 20 January 1992, 41).

Adding to the functionality of SMDS, in February 1992 Bellcore released a technical advisory report entitled Customer Network Management defining how users will manage nodes on an SMDS network. Some of the functions this report defines include adding and deleting addresses, and access SMDS usage data on carrier switches for internal chargeback purposes. An SMDS-oriented Simple Network Management Protocol (SNMP) management information base is specified that would enable an SNMP management system to handle devices on an SMDS network. The availability of these on-line management functions is key to the acceptance of SMDS by customers.

Service Providers

In February 1992, Bell Atlantic Corporation was the first carrier to file a tariff and gain FCC approval to offer an SMDS service. The service, referred to as "pre-SMDS," is based on the SMDS service specifications developed by Bellcore, but it lacks some of the features and capabilities defined in the full set of specifications. Specifically, features such as billing options, address screening, customer network management, and multiple addresses on a single network interface are not yet available. The SMDS service is based on two switches in Philadelphia and three in Pittsburgh, all of which are manufactured by Siemens-Stromberg Carlson.

The U.S. General Services Administration (GSA) was the first, and currently the only, customer to sign up for "pre-SMDS" service offered by Bell Telephone Co. of Pennsylvania, a subsidiary of Bell Atlantic. GSA is using SMDS to link two locations having more than 250 computers on three separate Ethernet LANs, transmitting database information and electronic mail between locations (Killette 3 February 1992, 4). GSA, once comfortable with the capabilities of SMDS, expects to expand its network to include between 10 and 15 sites. Other potential customers will most likely refrain from purchasing service on a large scale until tariffs have been approved and full SMDS services are offered.

As recently as May 1992, AT&T, GTE Telephone Operations, and Pacific Bell announced plans for the nation's first inter-LATA trial of SMDS. The primary purpose of this trial is to determine if interconnection and transport of SMDS traffic via a long-haul service provider's network is viable. As illustrated in figure 4-16, the test configuration will link NASA's Numerical Aerodynamic Simulation project center at Moffett Field, California, with Rockwell International Corp. sites in Canoga Park and Seal Beach, California (Wilson 18 May 1992, 5). AT&T will interconnect the SMDS networks provided by GTE and Pacific Bell by using DS-3 links and its BNS 2000 switching systems. NASA and Rockwell will access their respective regional SMDS switches via DS-1 links.

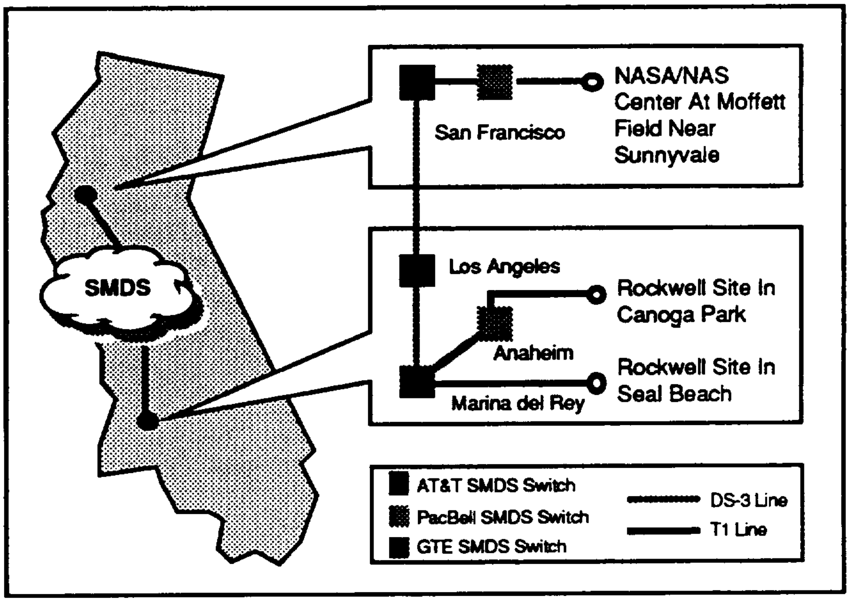
4.2.2.2 Plans

Service Providers

All of the RBOCs and GTE, which together provide telephone coverage to almost the entire United States, have announced plans to offer SMDS in many of the metropolitan areas they serve. As illustrated in figure 4-17, the timeframes for rolling out SMDS services vary between fourth quarter 1992 and the end of 1993 (Wilson 25 May 1992, 5). Although these companies have released few details on how these services will be interconnected among regions or planned pricing, SMDS is expected to be available in more than 40 cities by the end of 1993.

LECs have not yet defined equipment-certification and interoperability testing procedures for SMDS equipment. These certification and test procedures are required to ensure networkwide compatibility of equipment and will be needed before LECs can progress past the field trial stage. According to John Seazholtz, vice president of network technologies at Bell Atlantic, carriers are planning to seek assistance from the Center for Open Systems International, located in McLean, Virginia, for support in this area.

FIGURE 4-16
SMDS Field Trial



Source: Pacific Bell, *Communications Week*

FIGURE 4-17
SMDS Service Providers Plans

COMPANY	STATUS
Ameritech	Developing tariff; plans to announce user trials soon
Bell Atlantic	Has pre-SMDS available
BellSouth	Has been testing internally since 1989; has slated user trials for mid-1992; plans to deploy late 1992 or early 1993
GTE	Plans 3d quarter service rollout in California, 1993 in other states
Nynex	Plans service rollout for 1993
Pacific Telesis	Plans to file tariff soon; plans mid-1992 service rollout
Southwestern Bell	Has had user trial underway in Houston since December 1991
US West	Preparing tariff; plans June 1992 service rollout in 10 cities

Source: Wilson 25 May 1992

Although large long-distance carriers such as AT&T and MCI have not formally announced plans to offer SMDS, the industry consensus is that they will soon. Many of the LECs have publicly acknowledged that they are exploring the possibility of entering into agreements with long-distance carriers to ensure regional networks can be interconnected. AT&T, which has announced plans to participate in SMDS field trials, has the necessary equipment in place to offer SMDS. MCI has indicated it is examining market conditions for SMDS, but will exercise caution in announcing plans to support SMDS so as not to confuse customers who are using some of its other virtual network services (Taff 30 March 1992, 1).

Equipment Manufacturers

Basic equipment types unique to SMDS networks include SMDS-compatible routers, channel service units (CSUs), digital service units (DSUs), and cell relay switches. As illustrated in figure 4-18, a variety of vendors have announced plans to develop SMDS-compliant equipment with only a few of these vendors having commercially available products. While most LECs are planning, at least initially, to provide their SMDS services using the AT&T BNS 2000, a cell relay-based switching platform, other switches are available from Siemens-Stromberg Carlson, Fujitsu, and Northern Telecom.

FIGURE 4-18
Planned SMDS Equipment Product Lines

COMPANY	EQUIPMENT TYPE
CISCO	Routers
Wellfleet	Routers
KENTROX	CSUs/DSUs
Tellabs	CSUs/DSUs
AT&T	Switches
Northern Telecom	Switches
Fujitsu	Switches
Siemens - SC	Switches

Source: Manufacturers' literature

Much of the work that was initially done on the development of customer premises equipment for SMDS, such as routers and CSU/DSUs, was tied to proprietary standards. However, in late 1991, teaming agreements began to emerge between router and CSU/DSU vendors to develop a common interface standard. One nonproprietary standard that vendors are expected to comply with is called the SMDS Data Exchange Interface, which is based on the High-Level Data Link Control protocol that is widely used for other applications (Shultz 30 March 1991, 21). The movement away from proprietary standards by manufacturers will act to speed customers' deployment of equipment and carriers' deployment of services.

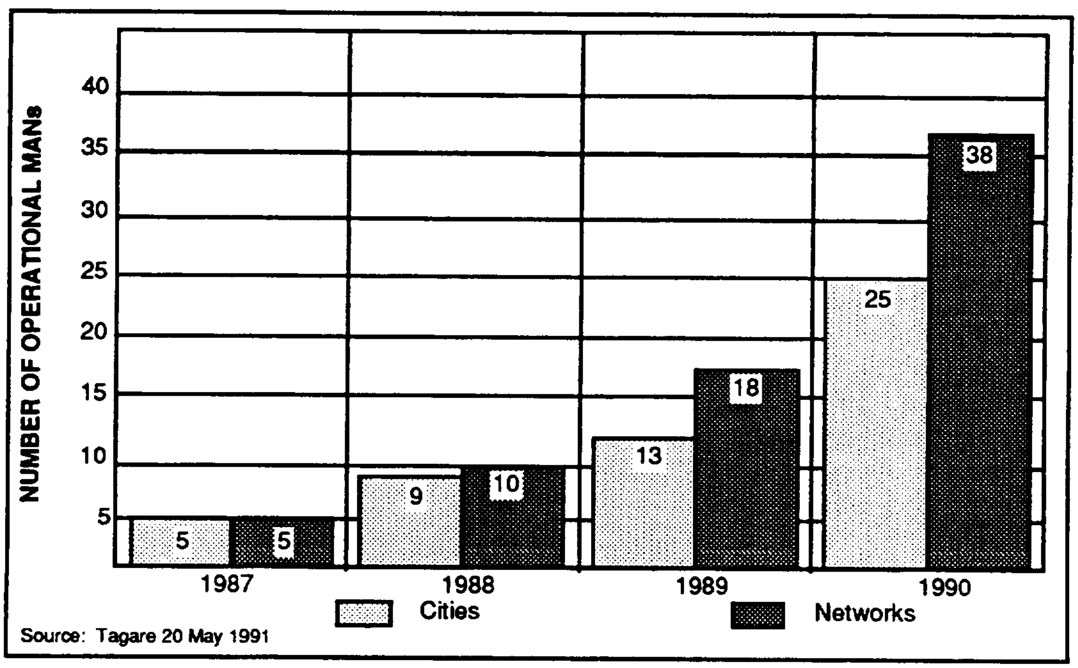
4.2.2.3 Deployment. Deployment of SMDS will be driven by factors of supply and demand. Factors of supply include well-defined standards for services and equipment that will simplify deployment, emerging technologies that will allow a cost-effective upgrade of subscriber links to support DS-1 and DS-3 access rates, and the overall desire of carriers to maintain market share while preparing for BISDN. Factors of demand will focus on user requirements for a cost-effective high-speed interconnection of LANs at multiple locations and their strategic positioning to take advantage of future BISDN capabilities.

Factors of Supply

The most important aspects and features for the success of SMDS are well-defined by Bellcore's service specifications. LECs, particularly RBOCs, are extremely strict in requiring that vendors ensure that products comply with defined standards before approving a product for use in their networks. Manufacturers of customer-premise type equipment are putting aside proprietary interface standards and working towards a common interface standard. These standards-related factors will help minimize service confusion and network interoperability problems and speed the deployment of SMDS.

Competition from alternative service providers offering access to MANs will provide the incentive for LECs to quickly deploy new services, such as SMDS, to avoid losing their market share. Competitors offering MAN services have only entered the picture within the last 5 years, but already their presence has affected the LECs. As illustrated in figure 4-19, by the end of 1990 there were 38 MANs operating in 25 cities, which is a sharp increase from the 5 networks operating in 1987. The cumulative investment in the MAN or alternative carrier industry has exceeded $300 million, including an investment of $115 million in 1990 alone. These networks are expected to generate revenues in excess of $200 million in 1991, representing an average annual growth rate of 84 percent since 1987 (Tagare 20 May 1991, 30).

FIGURE 4-19
Recent MAN Growth



Many carriers view SMDS as the first step towards deploying broadband services. Their desire to capture the broadband service market will likely result in carriers offering very flexible field trial opportunities to users in the hopes of luring potential customers. Depending on the actual rate of customer service acceptance, there may be a tendency on the carriers' part to offer very attractive pricing schemes to buy into the broadband market. Experience gained in the deployment of SMDS will be extremely valuable to carriers as they develop strategies for deploying BISDN.

SMDS, having DS-1 and DS-3 access rates, will be attractive to both large- and small-to-medium-sized businesses if priced competitively. Initial interest in the service will focus on the DS-1 access rate and will be deployed to customers already having facilities that can support this transmission rate. Over time, larger business customers will migrate towards the DS-3 access rate to meet higher speed LAN interconnect requirements. Emerging technologies, such as high-bit-rate digital subcriber line (HDSL), will allow the economical upgrade of existing copper plant to support DS-1 transmission and will place SMDS within the reach of small-to-medium-sized businesses.

Factors of Demand

The deployment of SMDS will be driven by the demand for LAN-to-LAN interconnects that can support a higher speed data transfer than is available with other technologies such as frame relay. As discussed in section 4.2.1.3, the demand for LAN interconnect hardware is projected to continue its rapid growth rate. Typically, remote bridges and routers, which operate at rates up to T1, are used to extend LAN capabilities. Because these links operate at rates significantly slower than the LANS they support (e.g., 10 Mb/s Ethernets and 4 Mb/s token rings), data transmission and processing bottlenecks occur. As LAN speeds increase to rates of 16 Mb/s for token rings and 100 Mb/s for Fiber Distributed Data Interface (FDDI), high-speed LAN interconnect services such as SMDS will be essential to support distributed processing over greater distances.

High-speed interbuilding or intercampus connections tend to be prohibitively expensive for many computing applications. Interconnection via a shared public network supporting SMDS offers an economically advantageous solution for end-users running these types of applications. Additionally, SMDS will fulfill the growing demand for high-speed links required to transparently interconnect different types of LANs such as token ring to Ethernet.

Deployment of SMDS will also be stimulated by the need to economically interconnect workstations (Bynre et al. January 1991, 69). Today, many workstations are connected to LANs, and data transfer between these workstations is accomplished via LAN facilities. In the future, as workstation capabilities increase with processor speeds, a growing number of these devices will be connected directly to the public network, via the necessary interface hardware, to allow direct high-speed workstation-to-workstation file transfer and data processing. An example of where this type of interconnection will be required is between workstations used for CAD/CAM applications at geographically dispersed locations.

4.2.2.4 Cost. The full cost of SMDS to the customer can be analyzed based on the service cost charged by carriers and the customer premises equipment required for interfacing LANs to the carriers' networks. Life-cycle cost for each implementation will then vary based on the number of locations to be interconnected, the number of LANs that need to be interconnected, the SMDS access rate desired, and if high-capacity digital facilities exist or must be constructed to support the chosen access rate.

Currently, one CSU/DSU and four router manufacturers have commercially available products. ADC telecommunications has priced its SMDS-compatible DSU at $15,000, and network systems has priced its high-speed router at $17,000, which is consistent with other vendor pricing. Within the next year, as carriers begin to sign up SMDS customers, we expect to see a greater number of vendors offering compatible products, similar to the frame relay equipment market. Additionally, because this is a higher-end digital service, we would expect to see more stability in product pricing with competitive pressures only resulting in a 10 percent reduction in pricing through 1995.

Little firm information has been released regarding the carrier pricing of SMDS. Service pricing strategies are expected to include both flat rate and usage-based options in addition to an up front one-time charge for configuring switching elements to provide the service. Bell Atlantic's pricing structure for its "pre-SMDS" service is based on a $500 per month access and unlimited usage charge, and a one-time $850 installation charge (Froyd 1992). Because this service does not include all of the features of true SMDS, the service is being offered to GSA at a discounted rate. Pricing for SMDS services is expected to be about $650 per month for access and unlimited usage, and a one-time installation charge of $1,000. Figure 4-20 indicates SMDS pricing levels that have been announced by several Bell operating companies and GTE. Most carriers will initially price their service to be competitive with current fractional-T1 rates for the lower speed SMDS access interface, with pricing strategies to be fully developed by late 1994.

FIGURE 4-20
SMDS Service Pricing

	PRICING		
COMPANY	MONTHLY	INSTALLATION CHANGE	ACCESS RATE
C&P of Maryland	$550	$1,000	1.17 Mb/s
C&P of Virginia	$550	$1,000	1.17 Mb/s
Bell of Pennsylvania	$600	$1,000	1.17 Mb/s
Pacific Bell	$600	$375	1.17 Mb/s
GTE	$700	$1,000	1.17 Mb/s

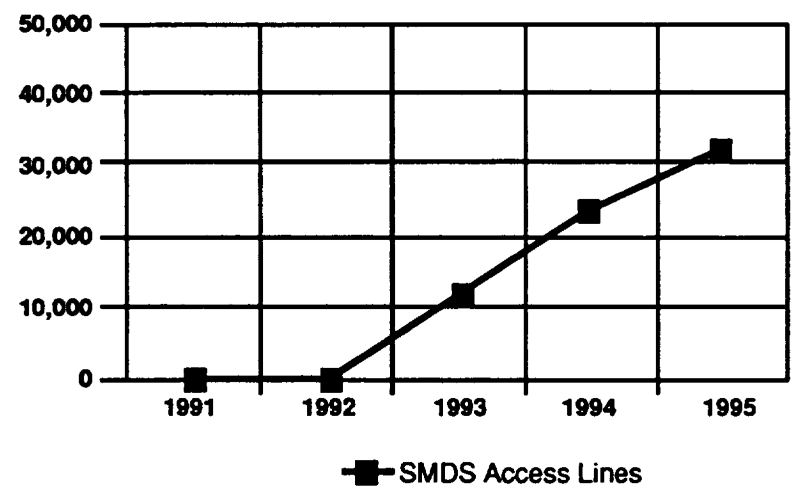
Source: Communications Week

4.2.2.5 Traffic. SMDS applications will account for a significant amount of domestic data transmission traffic. As illustrated in figure 4-21, SMDS is expected to exceed 30,000 access lines by the year 1995 (BIS Strategic Decisions). We expect to see continued rapid growth of computer-based applications that will require higher-speed links between a growing number of geographically-dispersed LANs through the year 2000. Around the year 2000, we expect SMDS to begin to serve as a means of accessing BISDN based on ATM in areas where BISDN is available.

Approaching the year 2010, as BISDN capabilities become more widely available, SMDS links will be upgraded or replaced by access links to support the BISDN interface rate of 155 Mb/s for most business users. Lower-rate access links will continue for smaller business applications.

SMDS traffic projections through the year 2011 are provided in figure 4-22. These projections are based on anticipated traffic levels developed in section 2.0, extrapolation of current SMDS market trends, and analyses of future technology availability and substitution. As indicated in the figure, SMDS traffic will include e-mail, terminal operations, and EDI and will primarily be generated through increased high-speed LAN-to-LAN interconnection. Based on Booz·Allen analyses, SMDS traffic growth is projected to level off around the year 2006 as BISDN becomes more widely available.

FIGURE 4-21
SMDS Market Forecasts



Source: *BIS Strategic Decisions*

FIGURE 4-22
SMDS Traffic Projections

DS0s	DS0 Units	Busy Hour Traffic Projections 1991	1996	2001	2006	2011
Voice						
MTS (Business)	DS0s (10^6)	-	-	-	-	-
MTS (Residential)	DS0s (10^6)	-	-	-	-	-
Private Lines	DS0s (10^6)	-	-	-	-	-
800	DS0s (10^6)	-	-	-	-	-
900	DS0s (10^6)	-	-	-	-	-
Private Networks	DS0s (10^6)	-	-	-	-	-
Data						
Facsimile	DS0s (10^3)	-	16.0	23.0	11.0	7.3
E-Mail	DS0s (10^3)	-	0.026	7.3	70	75
Terminal Operations	DS0s (10^3)	-	0.37	4.5	13.0	9.5
On-Line Info. Services	DS0s	-	-	-	-	-
EFT	DS0s (10^3)	-	-	-	-	-
EDI	DS0s (10^3)	-	0.035	0.35	0.80	0.41
Video						
Network Broadcast	DS0s (10^3)	-	-	-	-	-
Cable TV	DS0s (10^3)	-	-	-	-	-
Educational TV	DS0s (10^3)	-	-	-	-	-
Business TV	DS0s (10^3)	-	-	-	-	-
Viewer Choice TV	DS0s (10^3)	-	-	-	-	-
Traffic Allocation Factor *		0	0.05	0.25	0.5	0.25

* Traffic allocation factors are the fractions of total traffic that represent potential SMDS traffic.
Source: Booz·Allen Analysis

4.2.3 Broadband ISDN

BISDN represents the next major step in the evolution of the public switched telephone network. It is intended to support a host of interactive and distribution services ranging from voice to high-quality video. Based on an infrastructure of optical fiber transmission and fast-packet switching systems, BISDN can reduce the need for service-specific networks, thereby reducing overall network operating costs. BISDN is intended to extend the integration provided by ISDN within the loop plant to include the switching, signaling, and transport facilities required to support broadband services.

Concepts for a BISDN have been developed based on three fundamental service objectives:

- Increased end-to-end service capacity to support a variety of emerging high-bandwidth applications

- Increased network efficiency by allowing consolidation of different services onto a single network

- Enhanced network flexibility to lessen the impact of shifting user demand and future technology evolution.

To meet these objectives, the following technology platform for BISDN has been identified:

- The use of Synchronous Optical Network (SONET) transmission facilities to achieve network interface capabilities of 155 Mb/s and 600 Mb/s.

- The use of ATM switching to provide significant flexibility and efficiency in the provisioning of broadband services.

General services that BISDN is intended to support have been defined in CCITT recommendation I.211. As illustrated in figure 4-23, a wide range of interactive and distributive type services that support voice, data, video, text, and image communications have been defined. Services supported by BISDN fall into two basic categories: connection-oriented bearer services, and connectionless services (Study Group XVIII May 1990). Connection-oriented service has characteristics that require a connection to be established before communications begin. Connectionless services allow the connection between users to be established and disconnected at the same time that information is transferred. To further characterize BISDN services and relate them to network requirements, CCITT has defined the four basic service classes that are described in figure 4-24 (Study Group XVIII May 1990). In comparing the capabilities of frame relay, SMDS, and BISDN, the results show that frame relay supports traffic classes C and D, SMDS supports class D only, and BISDN is capable of supporting all four classes.

ATM, which represents a convergence of TDM and fast-packet switching, has emerged as the basic transport technology platform for BISDN. ATM is based on a 53-octet fixed-length cell that includes a 48-octet information field to carry user communications and a 5-octet header field that contains information used to route the cell to its destination. A benefit of ATM is that it allows the use of virtual connections rather than the fixed connections used in today's circuit switched networks. Additionally, similar to packet switching, ATM supports communications using bit rates that are matched to the actual user need, including time-variant bit rates.

The use of high-speed fiber optic transmission systems for BISDN is technically straightforward. Optical transmission systems operating in the gigabit range are being deployed

FIGURE 4-23
BISDN Services

Service Class	Type of Interaction	Examples of Broadband Services
Conversational	Moving pictures (video) and sound	Broadband video telephony Broadband video conference Video surveillance Video/audio information transmission services
Messaging Retrieval Services	Sound	Multiple sound program signals
	Data	High-speed unrestricted digital information transmission service High-volume file transfer service
	Document	High-speed telefax High-resolution image communication service Document communication service
	Moving archives (video) and sound document	Video mail service Document mail service
	Text, data, graphics, sound, still images, and moving pictures	Broadband videotex Video retrieval service High-resolution image retrieval service Document retrieval service Data retrieval service
Distribution Services Without User Individual Presentation Control	Video	Existing quality TV distribution Extended quality TV distribution – Enhanced-definition TV – High definition TV High-definition TV distribution Pay TV
Distribution Services With User Individual Presentation Control	Text, graphics, and still images	Document distribution services
	Data	High-speed unrestricted digital information distribution service
	Moving pictures and sound	Video information distribution services
	Text, graphics, sound, and still images	Full-channel broadcast video service

Source: CCITT Study Group XVIII

FIGURE 4-24
CCITT Service Classes

Criteria \ Class	A	B	C	D
Timing Relationship Between Source and Distribution	Required		Not Required	
Bit Rate	Constant	Variable		
Connection Mode	Connection-Oriented			Connectionless

Source: CCITT Study Group XVIII

for interoffice or trunking applications within carrier networks. In the future, optical transmission systems based on the SONET standards will provide common network access interfaces at 150 Mb/s (STS-3) and 600 Mb/s (STS-12) rates. In addition to a standard hierarchy for optical signals, SONET's flexible payload structure can accommodate virtually any type of digital signal and it provides a flexible platform for future services.

4.2.3.1 Status

Standards

Standardization of BISDN has been an ongoing process for the past 6 years. Since the approval by CCITT of I.121 in 1988, significant progress has been made in establishing BISDN principles and specifications. In November of 1990, CCITT approved the 13 BISDN recommendations listed in figure 4-25, which basically outline the fundamental principles for the next generation of telecommunications networks. These recommendations sufficiently stabilized the plans for BISDN, allowing the development of prototype equipment and the participation of carriers in initial BISDN field trials. For 1992, CCITT plans to enhance the 1990 recommendations with the objective of providing sufficient detail to allow basic BISDN service offerings as early as 1994 (Coudreuse August 1991).

Service Providers

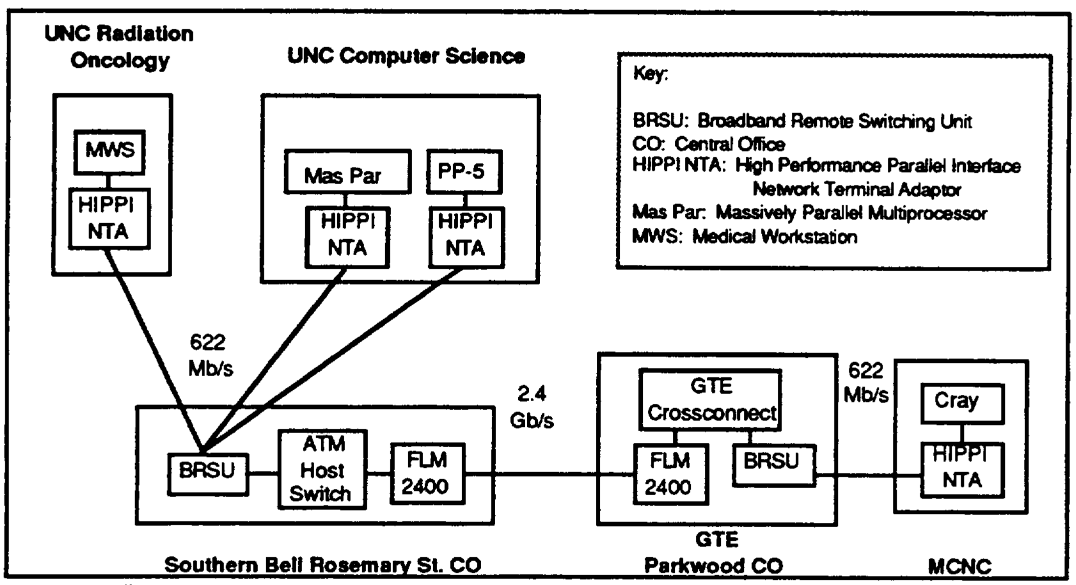
Currently, five BISDN field trials focusing on business and academic applications are being conducted by carriers. One example of the type of trials being conducted is VISTAnet, which represents a joint effort by GTE and BellSouth to provide BISDN services to several research facilities. As illustrated in figure 4-26, the VISTAnet field trial configuration includes broadband remote switch units at two serving offices with a controlling FETEX-150 host ATM switch in Chapel Hill. A 2.488 Gb/s SONET-based transmission system links the two central offices, and 622 Mb/s systems are used for customer access facilities from the four sites involved in the trial (Barsh et al. August 1991). The primary service application being employed in this trial is the transmission of medical imaging and the transmission of biological modeling data between facilities and computers. While VISTAnet is narrow in scope, carriers view these types of trials as critical to the development and further refinement of BISDN standards and supporting equipment.

FIGURE 4-25
CCITT 1990 BISDN Recommendations

General	I.113 Vocabulary of terms I.121 General broadband aspects I.610 Operations and maintenance
Services	I.211 Service aspects
Network	I.311 General network aspects I.321 Protocol reference model I.327 Functional architecture
Adaptation	I.362 Adaptation principles I.363 Adaptation specification
ATM Layer	I.150 ATM Functional characteristics I.361 ATM Specification
Physical Layer	I.413 UNI Reference characteristics I.432 UNI Specification

Source: CCITT

FIGURE 4-26
VISTAnet BISDN Trial



Source: IEEE Communications

As illustrated in figure 4-27, more than 48 field trials focusing on residential BISDN services are being conducted (TE&M Magazine January 1992). One reason for the high number of residential trials is that because BISDN can support major new residential service offerings, carriers are very interested in compiling market and cost data. Residential BISDN field trials are employing both fiber-to-the-home and fiber-to-the-curb architectures and they are offering a variety of services including plain old telephone service (POTS), data, video, and CATV.

FIGURE 4-27
U.S. Fiber Trials As of January 1992

Telephone Company	Location	End of Trial	Customers	Type*	Number of Lines	Services Provided
ALLTEL Corp	Matthews, NC	1990	Residential	FTTC	88	POTS
Ameritech	Columbus, IN	ongoing	Residential	FTTC	20	POTS/Video
Ameritech	Columbus, OH	ongoing	Residential	FTTC	64	POTS
Bell Atlantic	Loudoun County VA (Cascades)	late 1992	Residential	FTTC	122	POTS/Video
Bell Atlantic	Perryopolis, PA	1990	Residential	FTTH	90	POTS/Video
Bell Atlantic	Pitman, NJ	1989	Residential	FTTH	100	POTS
BellSouth	Asheville, NC	ongoing	Residential	FTTH	42	POTS
BellSouth	Charleston SC (Dunes West)	ongoing	Residential	FTTC	276	POTS
BellSouth	Charleston, SC (Lakeview Terrace)	ongoing	Residential	FTTH	85	POTS
BellSouth	Charlotte, NC (Morrocraft)	ongoing	Residential	FTTH	126	POTS
BellSouth	Chattanooga, TN (Council Fire)	ongoing	Residential	FTTC	163	POTS
BellSouth	Columbia, SC (The Summit)	ongoing	Residential	FTTH	285	POTS
BellSouth	Louisville, KY (Springhurst)	ongoing	Residential	FTTC	64	POTS
BellSouth	Marietta, GA (River Hill)	ongoing	Residential	FTTC	169	POTS
BellSouth	Memphis, TN (Grove of Riveredge)	ongoing	Residential	FTTH	99	POTS
BellSouth	Miama, FL (Coco Plum)	ongoing	Residential	FTTH	200	POTS
BellSouth	Orlando, FL (Heathrow)	ongoing	Residential	FTTH	256	POTS/ISDN/ Video
BellSouth	Orlando, FL (Hunter's Creek I)	ongoing	Residential	FTTH	250	Video
BellSouth	Orlando, FL (Hunter's Creek II)	ongoing	Residential	FTTH	117	POTS
BellSouth	Orlando, FL (Hunter's Creek III)	ongoing	Residential	FTTC	83	POTS/Video
BellSouth	Savannah, GA (The Landings)	ongoing	Residential	FTTH	216	POTS
Carolina Telephone (Sprint)	Corolla, NC	ongoing	Residential	FTTC & FTTH	90	POTS
Central Telephone (Centel)	Tallahassee, FL	ongoing	Residential	FTTH	13	POTS/Data
GTE Telephone Operations	Batesville, IN	1991	Residential	FTTC	80	POTS
GTE Telephone Operations & GTE	Cerritos, CA	1994	Residential	FTTC	250	POTS/Video
GTE Telephone Operations	Ridgecrest, CA	1991	Residential	FTTH	100	POTS
GTE Telephone Operations	Sydney, NY	ongoing	Business & Residential	FTTH	185	POTS
GTE Telephone Operations	Tampa, FL	Dec 1992	Residential	FTTC	115	POTS
GTE Telephone Operations	Wyoming, MN	1991	Residential	FTTC	100	POTS
NYNEX	Brooklyn, NY	1993	Residential	FTTC	330	POTS/Data/ Coin
NYNEX	Brooklyn, NY	1993	Residential	FTTC	527	POTS
NYNEX	Lynnfield, MA	1990	Residential	FTTC	122	POTS
NYNEX	Mechanicsville, NY	1993	Residential	FTTC	165	POTS

*FTTC = Fiber to the curb
FTTH = Fiber to the home

FIGURE 4-27
U.S. Fiber Trials As of January 1992 (Continued)

Telephone Company	Location	End of Trial	Customers	Type*	Number of Lines	Services Provided
NYNEX	Poughkeepsie, NY	1993	Residential	FTTC	530	POTS
NYNEX	Swampscott, MA	1993	Residential	FTTC	257	POTS/Burglar Alarm
Pacific Bell	Hawthorne, CA	start late 1992	Business & Residential	FTTC	394	POTS
Pacific Bell	La Crescenta, CA	ongoing	Residential	FTTC	295	POTS
Pacific Bell	Menlo Park CA (Raynet HQ)	1992	Business Campus	FTTC	142	POTS
Pacific Bell	Sacramento, CA (Sutter Bay)	planning	Business & Residential	FTTC	3000	POTS/Video/ Telecommuting
Southwestern Bell	Fort Worth, TX	1991	Residential	FTTH	25	POTS/Video/ Data
Southwestern Bell	Kansas City, KS (Leawood)	1989	Residential	FTTH	132	POTS/Data
Southwestern Bell	Kansas City KS (Olathe)	1991	Residential	FTTC	45	POTS/Data
U S West	Los Alamos, NM	1992	Residential	FTTC	160	POTS
U S West	St. Paul, MN (Mendota Heights)	1990	Residential	FTTH	100	POTS
U S West	Portland, OR (Milwaukie)	ongoing	Residential	FTTC	295	POTS
U S West	Scottsdale, AZ (Casa Privada)	1991	Residential	FTTC	70	POTS
U S West	Scottsdale, AZ (Desert Hills)	1990	Residential	FTTH	97	POTS
Vista-United Telecom	Orlando, FL	ongoing	Vista-United Office Pk.	FTTC	N/A	POTS/Video/ Data/ Coin

*FTTC = Fiber to the curb
FTTH = Fiber to the home

Source: Telephone Engineering & Management Magazine—A Light at the End of the Loop Supplement (January 1992)

Equipment Manufacturers

SONET equipment, which will serve as the primary transmission system standard for BISDN, has been available since 1989 and is widely deployed in the interoffice portion of most carrier networks. Phase 1 of the SONET standard, which identifies rates and formats and optical and electrical parameters, was completed and approved by ANSI in 1988. Based on the Phase 1 standard, all major transmission systems manufacturers introduced SONET-compatible product lines between 1989 and 1991. Phase 2 SONET standards, which cover the operation and management functions, are nearing completion. SONET-based systems are commercially available and support optical rates as high as OC-48.

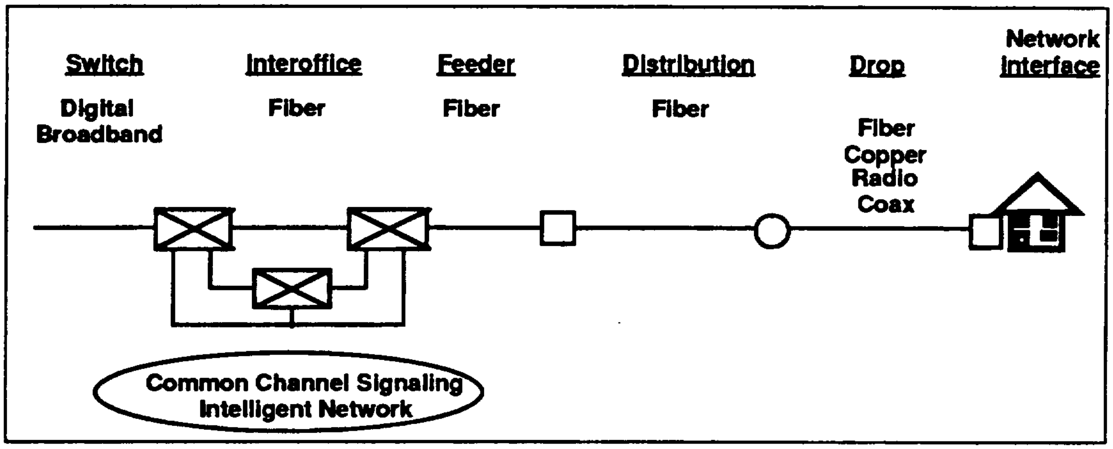
ATM equipment is under development with only a few vendors offering products, which are primarily designed to support private networking applications. Although the fundamental parts of the ATM standard have been completed and approved by ANSI and CCITT, work remains to be done on the user-to-network interface. The ATM Forum, which includes 43 primary industry members, is working to define specifications for the interface between an end-user device, such as a router or workstation, and an ATM switch. The interface also can be used between a customer premises switch and an ATM switch in the public network. Interface specifications that would be used for switch-to-switch interconnection within the public network have not yet been developed (*Communications Week* Staff 18 May 1991).

4.2.3.2 Plans

Service Providers

All major local exchange carriers are aggressively prosecuting plans to upgrade their networks to support broadband service offerings. These carriers are planning to upgrade their networks in two phases: extension of broadband transmission facilities to the customer, and upgrade of the switching fabric to include ATM capabilities. SONET-based transmission systems are being deployed by carriers in various fiber-to-the-curb and fiber-to-the-home configurations. As illustrated in figure 4-28, transmission links within LEC networks are generally categorized as interoffice, feeder, distribution, and drop. Although deployment architectures vary among carriers, most carriers are deploying SONET equipment for interoffice, feeder, and distribution links, and employing a variety of technical solutions for customer drops. Carriers are planning to deploy broadband switching capabilities to support large business customer applications first, gradually achieving widespread upgrade of their switching fabric to support ATM by the year 2010. Figure 4-29 illustrates the infrastructure upgrade plan announced by Bell Atlantic, which is consistent with plans reported by other major local exchange carriers (Bell Atlantic 1992).

FIGURE 4-28
LEC Network Transmission Links



Source: Booz-Allen & Hamilton

FIGURE 4-29
Bell Atlantic Infrastructure Upgrade Plans

BELL ATLANTIC	1984	1991	2000
Digital Switching	1%	56%	100%
Common Channel Signaling	0%	90%	100%
ISDN Offices	0%	58%	100%
Fiber IOF Routes	2%	75%	100%
Fiber Feeder Routes	0%	45%	100%
Fiber Distribution	0%	<1%	65%
Broadband Switching	0%	0%	8%

Source: Bell Atlantic

Major IECs, all of which are continuing to deploy higher speed SONET-based transmission systems, are also planning to support broadband services. For example, it has been reported that AT&T is planning to develop a Software-Defined Broadband Network (SDBN) that would support voice, data, and video traffic. The network would be based on an ATM/SONET technology platform and service offerings would be available in three versions: Data SDBN Service, Multimedia SDBN Service, and Voice-Only SDBN Service. Data SDBN would support data and image applications and provide for the migration of private-line networks to hybrid networks. Multimedia SDBN would support applications requiring any combination of voice, data, and video transmission including real-time computer data exchange. Voice-Only SDBN would be a more advanced version of the company's current software defined network voice offering, supporting a greater number of features. As illustrated in figure 4-30, AT&T plans to support ATM PVCs as early as 1994, followed by SVCs in 1995 (Wallace 30 March 1992).

FIGURE 4-30
AT&T Planned Network Technologies and Services

	Virtual and Public Services					Private-line Services	
	Switched T1 Carrier	SMDS Cell Relay	ATM switched virtual circuits	Broadband ISDN public cell relay	Frame relay	Private-line T-carrier	ATM permanent virtual circuits
Access Speed (bit/sec)	56K to 1.544M	1.544M to 45M	1.544M to 600M	56K to 600M	64K to 1.544M	56K to 45M	1.54M to 600M
Suitable Networks	Private and public	Private	Private and public	Standard public net for global service	Private and public	Private	Private
Suitable Traffic	Nonbursty	Bursty	Bursty and nonbursty	Bursty and nonbursty	Bursty	Nonbursty	Bursty and nonbursty
Availability	1990	1992	1995	1997	1991	1985	1994
Applications Supported	Voice, data, image, and video	Data and image	Voice, data, image, and video	Voice, data, image, and video	Data and image	Voice, data, image, and video	Voice, data, image, and video
Access Method	T1, Primary Rate Interface and 56 Kb/s DDS	T1 and T3	T1 to NxOC-1	T1 to NxOC-1	Fractional T1 to T3 and 56 Kb/sDDC	Fractional T1 to T3	T1 to NxOC-1
Switching Technology	Circuit switched	Fast packet	Fast packet	Enhanced ATM with ISDN signaling	Fast packet	Time-division multiplexing	Fast packet
Network Transit Delay	Less than 1 m/s	Less than 1 m/s	Less than 100 m/s	Less than 100 m/s	Less than 100 m/s	Less than 1 m/s	Less than 100 m/s
Call Setup Time	2 sec	0 sec	Less than 100 m/s	Less than 100 m/s	0 sec after predefining virtual circuit	0 sec after predefining circuit	0 sec after predefining virtual circuit

ATM Asynchronous Transfer Mode
DDS Dataphone Digital Service
NxOC-1 Multiples of 51.8 Mb/s Optical Carrier Level 1
SMDS Switched Multimegabit Data Service

Source: *Communication Week*

Equipment Manufacturers

Manufacturers of SONET-based transmission systems are providing systems that are designed to comply with Phase 1 SONET standards and are upgradable to Phase 2 SONET standards through circuit card replacement. Vendors, while continuing to develop higher-bit-rate systems for network backbone or interoffice applications, are focusing on the development of products that are specifically designed to support distribution and feeder applications. Equipment that supports transmission rates of up to 10 Gb/s is planned for trunking applications, while lower-bit-rate systems operating at 150 Mb/s and 600 Mb/s are under development to support direct fiber to the customer applications.

AT&T Network Systems and Northern Telecom, which together dominate the public network switch market in the United States, are both developing ATM switching systems.

AT&T's approach to providing ATM capabilities is based on the deployment of a new switching platform that will support cell-based applications as early as 1992, and will be evolvable to ATM by 1995. Northern Telecom is basing its system on its existing DMS/SuperNode, which will allow existing customers to provide ATM switching as early as 1993.

AT&T's Broadband Network Switch (BNS)-2000 is one element of AT&T's 2000 product line designed to support future BISDN requirements. Other AT&T 2000 series products will include the Broadband Remote Terminal (BRT)-2000 (a broadband remote switching module) and the Subscriber Loop Carrier (SLC) 2000. As illustrated in figure 4-31, the BNS-2000 platform will support a variety of servers including SMDS, frame relay, and X.25. The BNS-2000 is being introduced in two phases: Phase 1 is now available and can supports IEEE 802.6 point-to-point applications, and Phase 2, which will be available in the 1994 to 1995 timeframe, will support ATM applications (McQuillan Consulting 1992).

As illustrated in figure 4-32, Northern Telecom is planning to build on its existing switch architecture by adding broadband components to the DMS SuperNode platform. Basic switch components shown in the diagram include: the Synchronous Broadband Fabric, which provides bandwidth management and circuit switching at the DS-3 and STS-1 rates; ATM fabric with cell interfaces; and channel frame processors supporting signaling and broadband services. The layered resources approach will allow carriers to build broadband networks more cost effectively than with total switch replacement, and will allow a choice of service components based on application requirements (Northern Telecom).

FIGURE 4-31
BNS-2000 Architecture

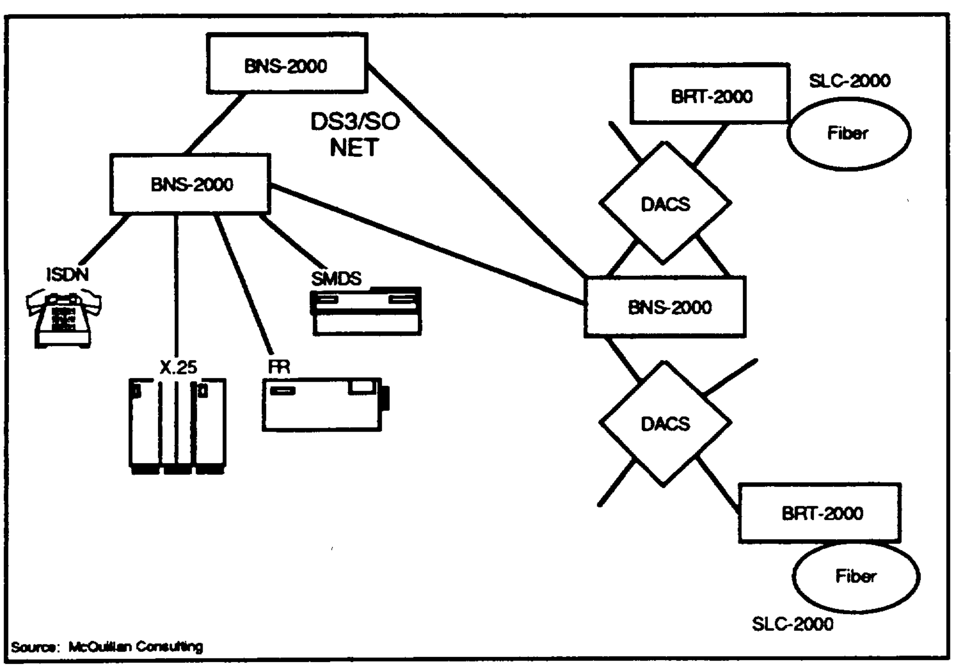
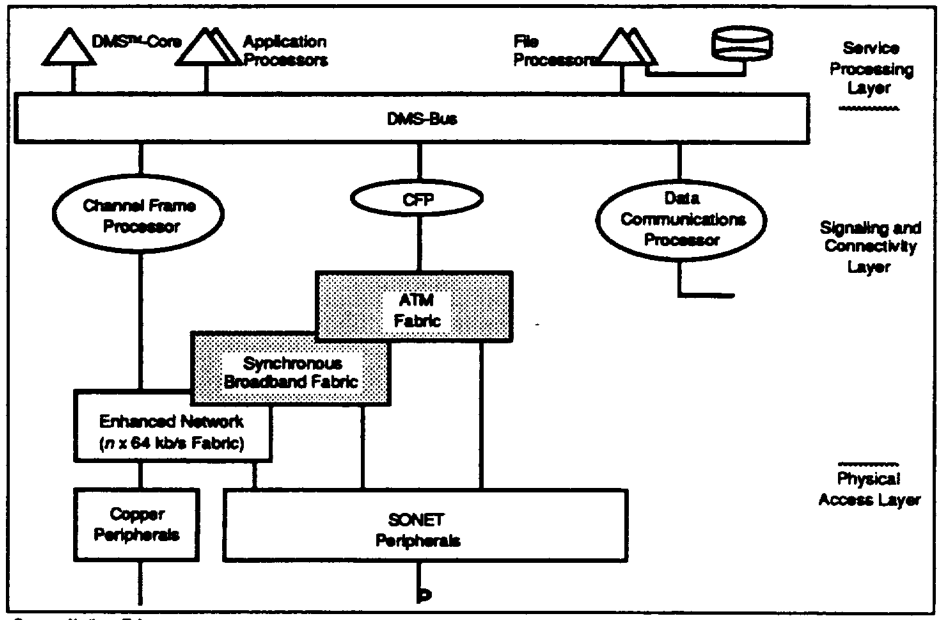


FIGURE 4-32
Northern Telecom Broadband Enhancements to DMS Supernode



Source: Northern Telecom

Most manufacturers of private network switches have also announced plans to develop ATM-compatible products. These switches would be used for providing BISDN capabilities within a private network, and for interfacing private BISDNs to public BISDNs to create a hybrid network. Because these switches are smaller and less complex in design than public switches, they are expected to be commercially available as early as 1992. Vendors differ in their approach to provide ATM capabilities from upgrading existing platforms by adding ATM interface to the introduction of entirely new switching platforms. Current private switch market leaders that have announced plans to develop ATM switching capabilities include: StrataCom, Newbridge, BBN, Fujitsu, and NEC. These switches are typically planned to support transmission rates of OC-1 and OC-3.

4.2.3.3 Deployment. Deployment of BISDN is the subject of much debate within the communications industry today. It is generally agreed that BISDN cannot be implemented universally, at least initially, but beyond this agreement projections of deployment rates vary widely (Walters September 1991). Ultimately, the large number of issues and concerns raised by those having a stake in the deployment of BISDN can be tied back to factors of supply and demand. The primary factors of supply that will affect the deployment of BISDN include technical challenges, regulatory constraints, and potential competition from other emerging technologies. Primary factors of demand that will affect deployment of BISDN include business customers' increasing need for broadband transmission capabilities, residential customers' interest and willingness to pay for expanded service offerings, and both business and residential users' acceptance of new technology.

Factors of Supply

Despite the inherent advantages of a universal BISDN, the development and investment costs associated with deploying such a network on a large-scale basis are prohibitive in the short term. Therefore, a major technical challenge that faces the communications industry is to allow the time-phased implementation of BISDN. Intermediate solutions must be designed to allow future integration with BISDN at the lowest possible cost. The industry consensus is that the migration strategy will include four phases: deployment to the customer of broadband transmission capable of supporting integrated services including ISDN, introduction of BISDN services, integration of MANs into BISDN, and the introduction of HDTV distribution via BISDN (Handel and Huber 1991).

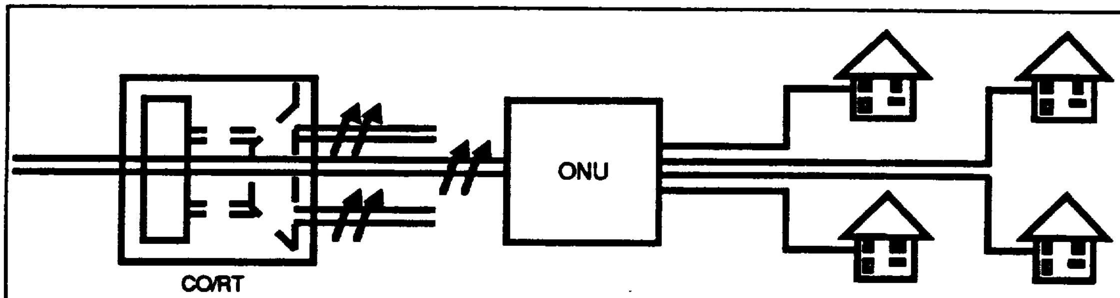
The direct deployment of high-speed fiber optic transmission systems to business customers is already being done in many metropolitan areas. The high level of traffic generated by large business users already makes this practice economically feasible for many applications. As the cost of transmission systems continues to decline and business data and image traffic continue to increase, deployment of fiber optic systems directly to customer premises locations will become a standard practice.

Deployment of broadband transmission capabilities to residential customers introduces a variety of economic issues for carriers. The demand for residential broadband services is expected to develop gradually; therefore the architecture used for deployment of fiber to residential customers must be cost competitive with deploying copper-based narrowband systems. As a result, several resource-sharing concepts, such as FTTC, have been developed that allow deployment of fiber as close to the residential customer as possible while remaining cost competitive. Figure 4-33 illustrates Bellcore's target architecture for FTTC systems, which brings high-bandwidth capabilities within a short distance (an average of 30 meters) of the residential customer. As demand for broadband services increases and video distribution is overlaid onto the BISDN, upgrade of FTTC architectures is possible, as illustrated in figure 4-34, through the use of advanced coding techniques, such as HDSL and ADSL, augmentation of copper pairs using coax or fiber, and finally, for maximum bandwidth, the introduction of WDM techniques (Bellcore June 1990). According to Bellcore estimates, one in five residences in high-growth areas will be served by FTTC by the end of the decade, with conversion to FTTH in these areas expected in the 2010 timeframe.

Although deployment of fiber to the customer need not be linked to the introduction of broadband service, the deployment of ATM switching is required to offer even the most basic broadband services. Based on CCITT recommendations for ATM, major switch manufacturers are planning to have products available in the 1994 to 1995 timeframe. Initial deployment of ATM switches by carriers will be in areas serving large business communities who will have an immediate need for new broadband services.

The introduction of broadband services will likely occur in three steps. During the first step, which will begin in the 1995 timeframe, carriers will begin offering a service equivalent to ATM private-line services or private virtual circuits that operate at access speeds of 1.544 Mb/s to 600 Mb/s and support voice, data, and video applications. In the second step, which will occur in the 1996 timeframe, carriers will introduce ATM switched virtual circuits that operate at access speeds of 1.544 Mb/s to 600 Mb/s and support voice, data, and video applications. The third step, occurring in the 1998 timeframe, will represent the full realization of BISDN deployment as carriers introduce a diverse set of switched and virtual services to business customers and, on a limited basis, to residential customers. Widespread availability of broadband services to residential services will not be fully realized until the 2010 timeframe, which coincides with the planned schedule for the complete upgrade of subscriber loops.

FIGURE 4-33
Bellcore FTTC Architecture



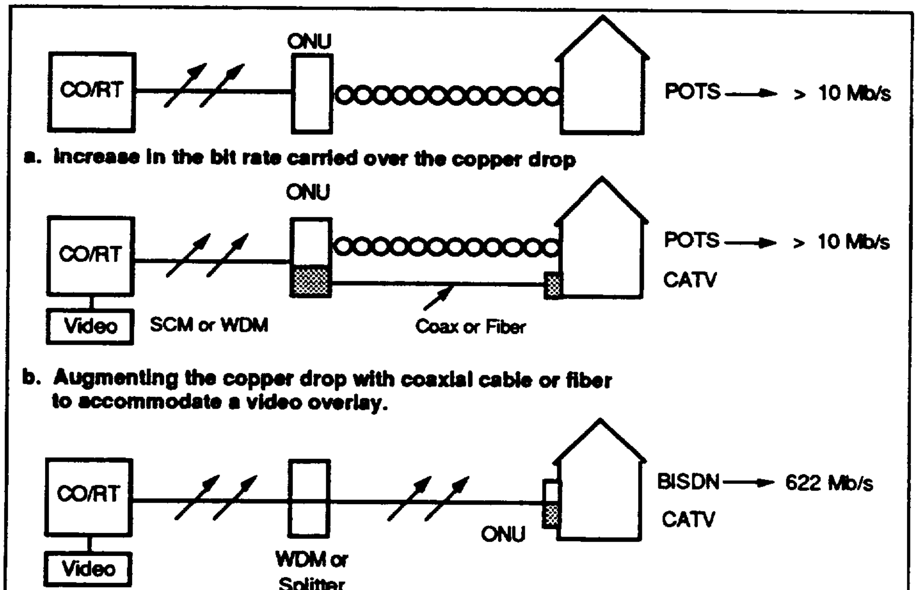
- FTTC
- Two Unique Fibers/ONU (Physical Star Topology)
- Four Living Units ≥ 12 DS-Ss/ONU
- Traditional Crossconnect Functionality not Desirable
- Compatible With TR-303 (Integrated DLC)
- Capable of Video Transport for 42-60 NTSC VSB-AM Channels
- Compatible With Eventual BISDN Upgrade

Key:

CO: Central Office
RT: Remote Terminal
BISDN: Broadband ISDN
NTSC: National Television System Committee
VSB-AM: Vestigial Sideband-Amplitude Modulation
ONU: Optical Network Unit

Source: Bellcore

FIGURE 4-34
FTTC Upgrade Options



a. Increase in the bit rate carried over the copper drop

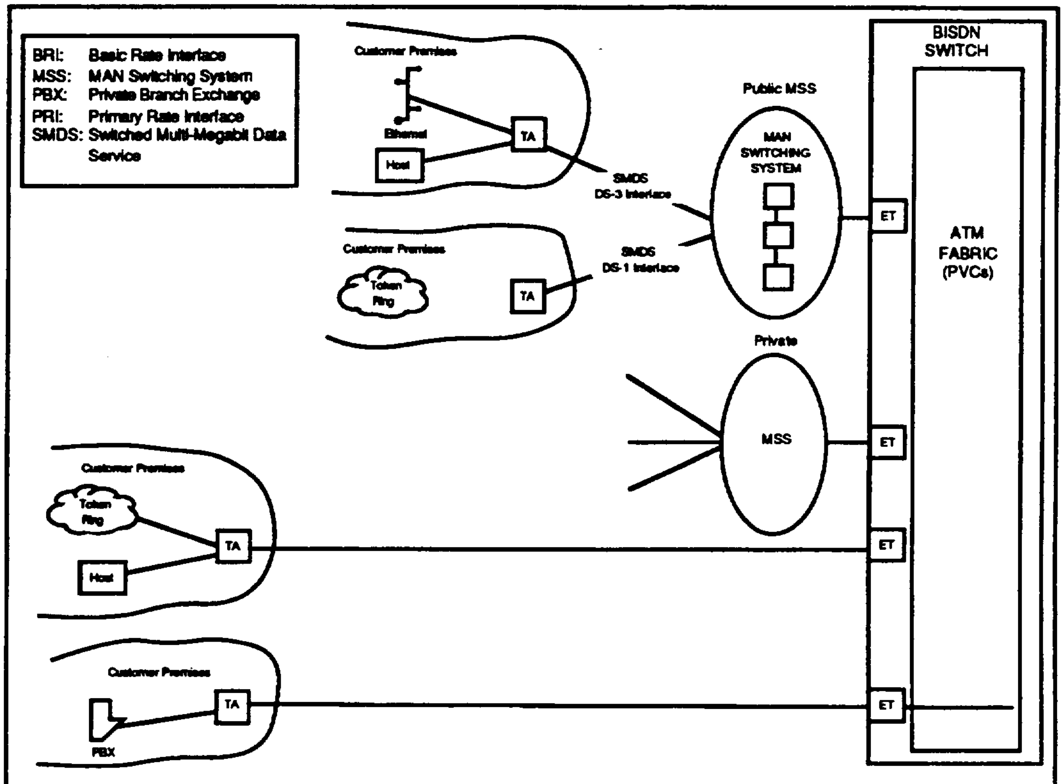
b. Augmenting the copper drop with coaxial cable or fiber to accommodate a video overlay.

c. Evolving to FTTH for all services (including video overlay possibility).

Source: IEEE Communications Magazine

The introduction of BISDN will allow the interconnection of both private and public MANs via public switched network facilities, as illustrated in figure 4-35. The compatibility of MANs being deployed today, such as SMDS, with ATM will enable these systems to provide access to the BISDN and the host of service capabilities it supports. Interconnection of MANs will provide users access to wider areas with more flexibility, low transmission delay, and high throughput. With the introduction of BISDN, we expect to see fewer users implementing private LAN or MAN interconnection schemes, using instead BISDN.

FIGURE 4-35
MAN Interconnection Using BISDN

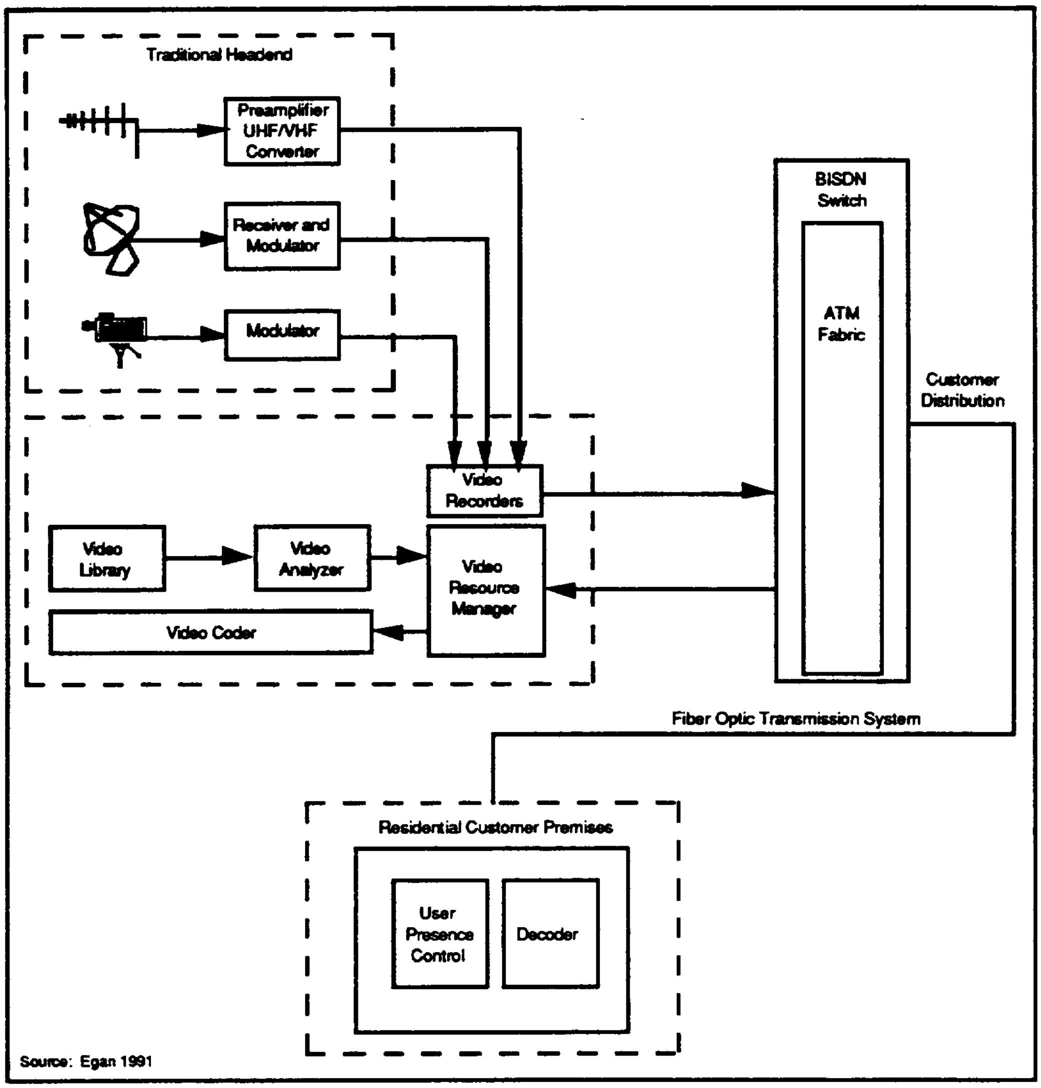


Source: IEEE Communications Magazine

Over time, as a result of the increased flexibility, expanded services, and lower costs that BISDN is able to offer over MANs, Booz·Allen expects to see a reduction in the number of private and public MANs implemented. Long term, Booz·Allen expects to see the total replacement of MANs by services offered via BISDN with the transition of services being totally transparent to the user. The widespread availability of LAN and terminal equipment supporting ATM will allow users to connect directly to the BISDN, reducing networking costs while improving overall service flexibility (Byrne et al. January 1991).

Distribution of video programming via BISDN is primarily targeted at the residential marketplace. Early planning of BISDN during the late 1970s focused on video distribution to the home as the only important residential service (Kishimoto August 1991). Since that time, while the distribution of video remains an important potential service, it is not viewed as the only reason to extend BISDN capabilities to residential users. LECs hope to, or are planning to, offer services and capabilities that traditional CATV providers cannot or have not, such as video on demand and access to other information services. A variety of architectures have been proposed for the distribution of video signals via BISDN. As illustrated in figure 4-36, major elements common to these distribution architectures include the interconnection of programming sources to BISDN, high-capacity links extended to the end-user, and the necessary interface equipment to allow the end-user to select video signals.

FIGURE 4-36
BISDN Video Distribution Architectures



Despite the economies of scale associated with offering video distribution via BISDN, cable television companies and over-the-air broadcasters view the deployment of fiber-to-the-home as a threat to their business base and will slow the migration of these service onto BISDN. Both CATV and over-the-air broadcasters have significant network investments at stake and will mobilize well-organized regulatory lobbying groups to protect their interests in the near term.

Long term, Booz·Allen analysis anticipates that the emergence of HDTV and VOD services will provide a large source of BISDN traffic, taking advantage of the inherent capabilities of the network. Digital coding, transmission, and switching of video via BISDN will offer considerable advantages over conventional analog distribution in terms of image quality, control, and the variety of VOD services that can be offered to the customer. The FCC is evaluating five proposals for HDTV signal standards in the United States, four of which require the transmission of video in the form of digital data within the 6 MHz bands (Hassinger August 1991; Beakley1992). Additionally, each of these approaches assumes the availability of approximately 15 Mb/s for encoding the video information after provision is made for error correction, audio, and data. The planned deployment of fiber to residential customers combined with the advanced signaling capabilities of BISDN will result in BISDN emerging as the primary platform for distributing VOD programming on a widespread basis around the year 2010.

The current and future regulatory environment in the United States will directly affect the deployment of BISDN. In general, restrictive regulatory policies will serve to slow the deployment of BISDN by LECs, while more flexible regulation that allows LECs to offer information services will encourage carriers to invest in new technologies and speed the implementation of BISDN. Although Congress and State and local governments can play a role in the development of telecommunications carrier regulation, the primary forces at work today and in the near future will continue to be the Modified Final Judgment (MFJ) handed down by the courts in the AT&T divestiture decision and FCC common carrier regulation.

The MFJ as it stands today introduces public policy problems for the widespread deployment of BISDN. Specifically, the provision of the MFJ that could affect BISDN deployment relates to the line-of-business restrictions placed on the RBOCs. These restrictions preclude the RBOCs from offering new and enhanced network services including videotext, broadcast video, and information services. Although the decree does not prohibit the RBOCs from providing basic network switching and transmission functions for other service providers, it does require carriers to adhere to a number of strict regulations. Since 1986, several legislative initiatives have been undertaken by Congress to override the MFJ and current restrictions on the RBOCs, particularly with respect to the telephone companies' provisioning of CATV services. We expect that continued lobbying by the RBOCs and the efforts by other government agencies that disagree with the MFJ, such as the National Telecommunications and Information Administration, will lead to the removal line-of-business restrictions in the 1996 to 2000 timeframe, providing further incentive for the acceleration of BISDN deployment.

FCC common carrier policy regarding cost allocation, rate regulation, and depreciation will affect the deployment of BISDN. One major change already under way is the movement from the pervasive rate-of-return regulation of common carriers to direct price regulation, or price caps. This fundamental change, if adopted, will greatly enhance the prospect of carriers deploying BISDN. By only regulating price levels for basic services, which is the key variable to consumers, most of the problems associated with complex cost-allocation schemes, inflexible pricing and depreciation, are mitigated (Egan 1991).

Competition from emerging technologies and other service providers will pressure carriers to deploy BISDN as quickly as possible to avoid loss of their market share. The CATV industry is rapidly deploying fiber optic transmission systems based on a fiber-trunk-feeder architecture for use in delivering entertainment video. Annual fiber deployment, which began in 1988, grew to 53,000 fiber miles in 1990, and is expected to reach 154,000 fiber miles in 1992 based on projections by Paul Kagan Associates. The continued rapid investment by the CATV industry in fiber facilities reduces the likelihood that entertainment video will migrate onto a single BISDN in the near term. Additionally, with the extension of high-capacity fiber links to the customers, the CATV industry is well positioned to compete with carriers in the delivery of other information services.

The potential threat of other service providers capturing market share will force RBOCs to deploy BISDN even before demand exists. This is an immediate concern for RBOCs in light of the recent development in PCN and the number of service providers other than the local telephone company deploying facilities in the local loop. Carriers will be unable to take a wait-and-see approach to the deployment of broadband service or the emergence of cheaper delivery systems and will be driven to replace existing copper loop plant with fiber facilities. Both LECs and cable TV companies have aggressive plans to upgrade their networks, investing large sums to capture part of what they perceive to be a very lucrative market.

Factors of Demand

Demand for services that will be supported by a BISDN can be broken down into two major segments: business and residential. Business services will be characterized by high-bit rate connectionless data transfer to support the growing demand for information retrieval and transfer among computers, and variable-bit rate services to support rapid growth in image traffic. Residential services will be focused on providing entertainment programming and convenience services such as in-home shopping and banking, and a host of other information services that require access to greater bandwidth.

Business broadband service demand will be primarily driven by trends in the computer industry. Traditional computing environments, such as mainframe host computers that are accessed via hierarchical networks of terminals, are being replaced by mesh-connected LANs that interconnect powerful workstations and personal computers (Frame April 1990). Text-based transactions are evolving to image-based transactions supported by file servers. This distributed networking architecture with bursty traffic characteristics is driving the demand for broadband networking capabilities over a wide geographical area.

Image transfer is also emerging as a requirement in many nontraditional business environments, such as the medical and advertising fields. The transfer of medical X-rays between doctors' offices and health care facilities has received increased attention as the result of recent broadband field trials and is considered to be a rapidly growing application. Transfer of medical X-rays from a radiology center to an end-user, such as a doctor or hospital, will typically require 50 Mb/s for a high-quality image to be transmitted in less than 1 second (Frame April 1990).

The demand for residential broadband services will stem from the demand for entertainment services. Residential entertainment services have evolved from only a few broadcast channels to more than 50 CATV channels, 100 to 150 satellite channels, VCR tape rentals, pay-per-view options, and several premium movie CATV channels. As the choice in entertainment services has grown, the average time that television is watched per household has grown from 4 to 8 hours per day. The strong market for entertainment services is further illustrated by the fact that of the 86 percent of the U.S. households that have access to CATV, 55 percent subscribe to basic service. Additionally, 30 percent of the homes that are served purchase one or more premium channels and 10 percent use pay-per-view services (U.S. Department of Commerce Industrial Outlook Report, 1991). Carriers' approaches to this market will be a combination of increasing the number of programming channels available to each customer and offering viewer control in selecting video programming and services, such as through VOD.

In addition to the trend of growing choice in residential entertainment services, there has been a parallel trend in the demand for improved video quality. This is similar to the trend in audio programming that has resulted in the proliferation of compact disk systems. HDTV represents the next major step forward in improving the video quality available to residential customers. Once HDTV signal formats are agreed on for the United States, BISDN will a major technology platform for serving this market.

4.2.3.4 Cost. Tariffing of future broadband services will be the most important factor influencing the widespread acceptance of BISDN by customers. As BISDN is deployed, carriers face two tariff-related issues: what service tariff components should be defined rather than usage-based; and as existing services transition to BISDN, how can carriers ensure the smooth transition of tariff-based costs (Handel and Huber 1991).

In today's networks, service charges are usually expressed in terms of basic rate charges and traffic charges. Basic rate charges are paid by customers for network access irrespective of a customer's actual traffic load. Traffic charges may be determined based on a variety of parameters, which may include establishing/releasing connections, connection time, traffic volume, or flat rate. In today's networks, voice calls are usually charged based on their connection time. For data transmission in packet networks, charges are normally based on volume of traffic, with an additional small charge for establishing and retaining a connection.

In the ATM-based BISDN environment of the future, which will be capable of providing both continuous bit rate and packet-type services, service charges is a complex issue that has not been fully resolved by standards groups. Although all information will be transmitted in ATM cells, simple volume-dependent charging similar to that used in today's packet networks would not be reasonable for all services (Toda April 1990). For example, continuous bit rate services such as voice service or a 15 Mb/s video service would result in charges so high that the service would rarely be used by customers. Discussions within CCITT on charging in ATM-based networks have identified some general charging principles, but detailed charging procedures are not yet available.

The current thinking is that future rate structures would include two parts: a basic charge and a usage charge. The basic charge would reflect the cost of provisioning customer access and would depend on the maximum bit rate the customer requires. The usage charge would be made up of two components: a call setup charge that is the same for all calls and a traffic-dependent charge that is determined by call duration and bit rate. It is anticipated that the traffic-dependent component would increase less than linearly with bit rate to make BISDN cost-effective for high-bit-rate applications.

4.2.3.5 Traffic. Booz·Allen's view is that BISDN will account for a growing amount of traffic beginning at low volume in 2001 and rapidly escalating through the year 2011. Business applications will account for initial BISDN traffic, which will continue to grow as existing services are migrated onto BISDN and additional networking capabilities are introduced. As carriers continue to deploy fiber optic transmission systems in the subscriber loop, broadband services will be made available to a growing number of residential customers, with initial service offerings beginning around the year 2000, followed by widespread availability of service by the year 2010.

BISDN traffic projections through the year 2011 are provided in figure 4-37. These projections are based on anticipated traffic levels developed in Section 2.0, extrapolation of current B-ISDN market trends, and analyses of future technology availability and substitution presented in this section. As indicated in the figure, BISDN traffic will include the full range of voice, data, and video traffic types described in this report. Rapid growth in data and image traffic combined with overall network operation cost savings will speed the transition to BISDN. Booz·Allen's estimate is that rapid BISDN traffic growth will begin around the year 2006 and continue through the timeframe of this study period.

FIGURE 4-37
BISDN Traffic Projections

DSOs	DS0 Units	Busy Hour Traffic Projections 1991	1996	2001	2006	2011
Voice						
MTS (Business)	DSOs (10^6)	-	-	0.145	1.10	3.2
MTS (Residential)	DSOs (10^6)	-	-	0.011	0.080	0.24
Private Lines	DSOs (10^6)	-	-	0.105	0.43	0.70
800	DSOs (10^6)	-	-	0.036	0.24	0.65
900	DSOs (10^6)	-	-	0.0008	0.0050	0.0125
Private Networks	DSOs (10^6)	-	-	0.0065	0.065	0.190
Data						
Facsimile	DSOs (10^3)	-	-	4.5	5.5	14.5
E-Mail	DSOs (10^3)	-	-	1.45	35.0	150
Terminal Operations	DSOs (10^3)	-	-	0.90	6.5	19.0
On-Line Info. Services	DSOs	-	-	0.00195	0.023	0.115
EFT	DSOs (10^3)	-	-	0.25	1.45	3.1
EDI	DSOs (10^3)	-	-	0.070	0.40	0.83
Video						
Network Broadcast	DSOs (10^3)	-	-	0.73	3.63	7.3
Cable TV	DSOs (10^3)	-	-	2.8	20	48
Educational TV	DSOs (10^3)	-	-	0.85	6.5	14.0
Business TV	DSOs (10^3)	-	-	7.5	48	98
Viewer Choice TV	DSOs (10^3)	-	-	24	240	1100
Traffic Allocation Factor*		-	-	0.05	0.25	0.5

* Traffic allocation factors are the fractions of total traffic that represent potential BISDN traffic

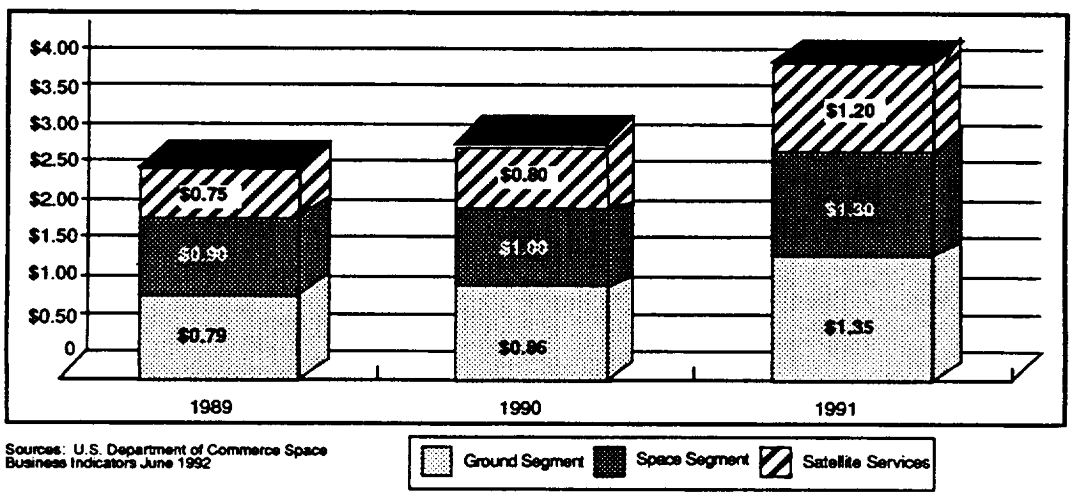
Source: Booz·Allen Analysis

4.3 SATELLITE SYSTEMS

Satellite systems can be characterized based on three general categories of services provided: fixed, broadcast, and mobile. Fixed satellite systems transmit to stationary earth stations that may require relatively large antennas based on specific traffic requirements and are capable of supporting voice, data, and video applications including television distribution. Direct broadcast satellite systems also use fixed earth stations for video or television distribution, which are typically much smaller than those of fixed systems, but also may use mobile terminals for some audio applications. Mobile satellite systems support a variety of low-bit rate service and typically use mobile terminals with small antennas. The focus of this section is on fixed and direct broadcast satellite systems that share similar space and ground segment infrastructures. Mobile satellite systems are addressed separately in section 4.5.

As illustrated in figure 4-38, the services and equipment markets for satellite communications grew by about 9 percent from 1989 to 1990 and by about 45 percent from 1990 to 1991. The space segment consists of the satellites themselves; the ground segment consists of satellite comunication terminals and equipment; satellite services represent the revenue from sales of communication services. All of these numbers exclude the relatively small revenues from remote sensing and the revenues from satellite launch services.

FIGURE 4-38
U.S. Commercial Space Sector Revenues ($ Billions)



Sources: U.S. Department of Commerce Space Business Indicators June 1992

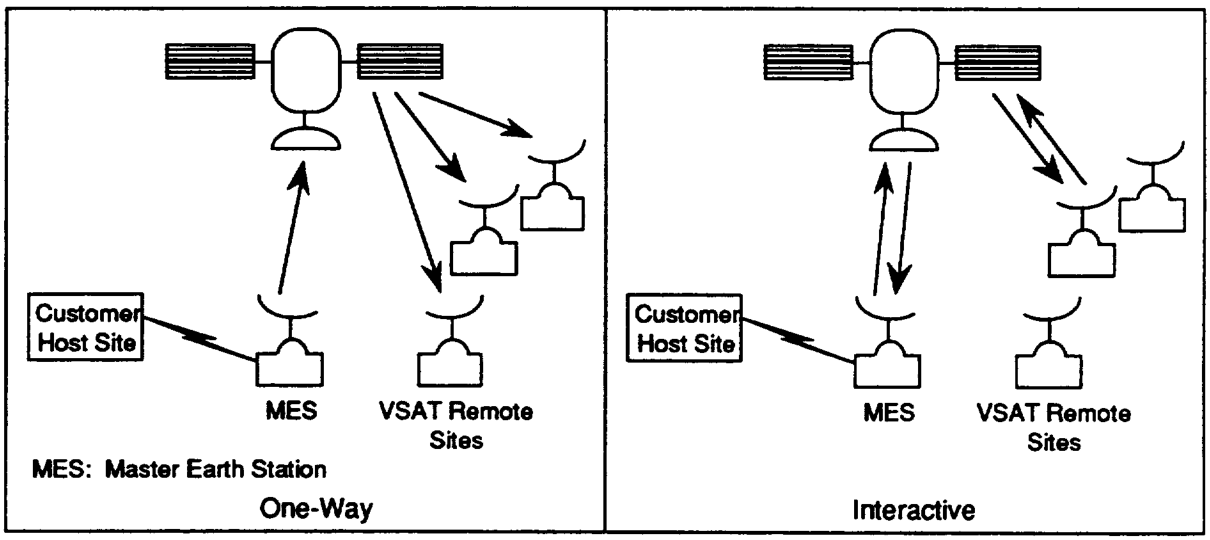
The year-to-year increases in these 3 market segments were rather uniform. From 1989 to 1990, the 3 segments increased between 7 and 11 percent. From 1990 to 1991, the increases were 30 percent for the space segment, 50 percent for satellite services, and 57 percent for the ground segment. In all 3 years, each of these 3 segments accounted for about a third of the total. The space segment is inherently more volatile on a year-to-year basis than the other segments because there are relatively few launches each year of very expensive satellites.

Over the next few years, the advent of mobile satellite services, both GEO and LEO, will increase the level of investment in space segment and smooth the year-to-year variations because the LEO systems use many small satellites. For instance, Motorola's Iridium project would account for about $3 billion in outlays alone. At present, there are more than 12 potential systems planned for start-up before the year 2000; four are geosynchronous orbit systems and eight are low-earth orbit systems. Natural interference problems could preclude some of these systems from being launched. Direct Broadcast Satellite is also a potential source of increased investment in the space segment with 11 direct broadcast television systems proposed for the near future. These systems will substantially add to the terrestrial segment but probably over a longer time period as the services are accepted by consumers.

4.3.1 Very Small Aperture Terminals (VSAT)

A VSAT is typically defined as a small fixed earth station with an antenna diameter less than 2.4 meters that is suitable for easy installation on customer premises. VSAT networks typically are arranged in a star configuration and consist of a master earth station (hub), remote terminals, and a space segment (airtime). Figure 4-39 depicts two typical VSAT network configurations: one-way data broadcasting networks and fully interactive networks.

FIGURE 4-39
VSAT Network Configuration



Source: Booz·Allen & Hamilton

Satellite technology has the important feature of providing the user with the option between full duplex transmission, as in interactive networks, or simplex transmission, as in one-way data broadcasts networks. One-way data broadcast networks are point-to-multipoint networks where a hub station broadcasts packetized data, program quality audio and/or video, or a combination of these transmissions to remote receivers; no communications take place in the opposite direction. One-way systems, unlike terrestrial alternatives, can simultaneously distribute information to several remote locations. For instance, one type of terrestrial alternative, distribution through leased lines, requires sequential access to each node on the system. In addition, the return transmission path inherent to leased lines, which are full-duplex, is unnecessary because this type of application does not require two-way communications (Caprioglio March 1992).

Interactive networks offer a wide range of two-way voice, video, and data services through a central hub station to remote VSATs. This star configuration requires two sets of up and down links to accomplish point-to-point communications among VSATs, therefore doubling the transmission delay inherent to satellite communications. The 500-millisecond (round trip) delay that results from a star configuration makes interactive voice communications unacceptable in most domestic markets. However, single hop voice communications from the VSAT to the hub is of acceptable quality to most users.

A hub has three main components: the radio frequency (RF) subsystem, the intermediate frequency (IF) subsystem, and the baseband subsystem. The RF subsystem consists of an antenna (typically 6 to 9 meters in diameter) a low noise receiver, and an RF radio. The RF subsystem processes the IF analog signal, converts it to higher frequency RF signals, and transmits the signal to the satellite. The IF subsystem converts the analog IF signals from the RF subsystem into digital data streams, each of which contains the packets from inbound transmission. The IF subsystem also receives information from the baseband subsystem and converts it to an analog signal for outbound transmission. The hub's baseband subsystem performs protocol conversion and multiplexing/demultiplexing, and includes interfaces to user host equipment (Polti and Stein February 1991).

VSAT equipment consists of an antenna dish, an RF electronics package, a mounting frame, a controller, which incorporates the modulator/demodulator, a microprocessor for data communications, and a microprocessor to provide protocol handling for interfacing with terminal equipment.

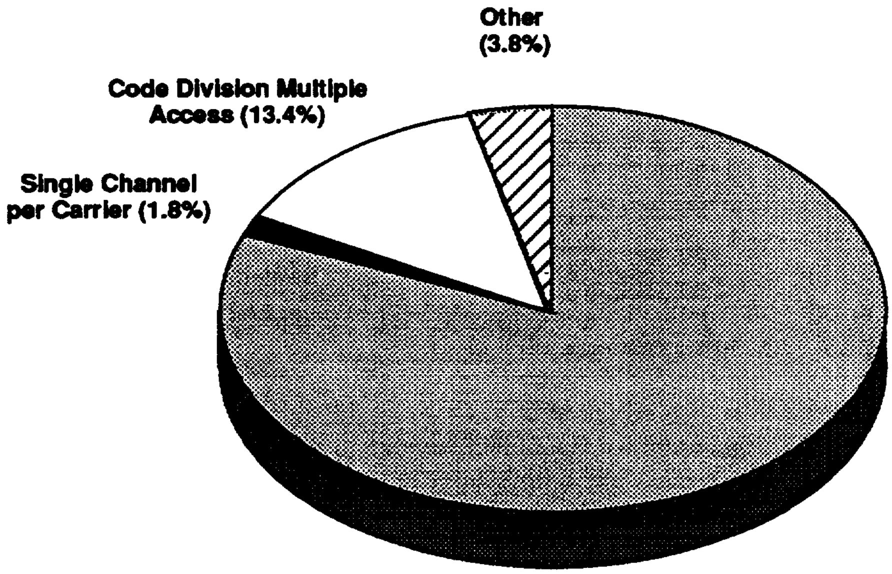
Present commercial VSAT networks transmit and receive at C or Ku frequency bands. Experimental VSAT systems are planned for operation in the Ka band. Because C-band systems share frequencies with terrestrial microwave systems, their use in congested areas is severely limited. For this reason, C-band systems are used more overseas where point-to-point microwave systems are less numerous and create less of an interference problem. Ku-band systems do not share frequencies with terrestrial networks and do not have the same interference problems as C-band systems. Although systems operating on adjacent satellites can interfere with one another, Federal Communications Commission (FCC) regulations mitigate this problem.

Networks with a small number of remote locations (i.e., nodes) may find owning and operating a dedicated hub prohibitively expensive. However, VSATs can still provide economical service to these networks through the use of shared-hub facilities. Shared-hub facilities can provide economical access to small groups of terminals. In a shared-hub configuration, the host computer is connected to the hub earth station by a either a leased-line or microwave link rather than being collocated with the hub. Although this connecting link introduces another cost to the network, the incremental cost is compensated for by the savings on hub costs.

Typical installations transmit data at up to 128 kb/s and receive at 512 kb/s. These limits are being pushed back by technological advances in VSAT design that allow data communications rates of 1.544 Mb/s (T1) or 2.048 Mb/s (E1).

Satellite transponder user costs are based on the amount and priority of bandwidth used. The increasing pressure from the FCC for radio spectrum users to become more efficient in their use of bandwidth has spurred the use of spread-spectrum transmission technologies in VSAT networks. Spread-spectrum techniques may also be used in VSAT networks to remain within the FCC power density limits, for higher availability or to limit interference with adjacent satellites. As figure 4-40 illustrates, TDMA has become the dominant transmission technology in today's VSAT systems (RKM Associates 1991).

FIGURE 4-40
Market Share by Transmission Protocol



Source: RKM Associates

Recent developments in technology have enabled new VSAT configurations that can capitalize on advances in microprocessor design. By placing greater computing power at the VSAT, the VSAT can handle network management functions, thereby eliminating the need for a master earth station. Such networks are configured in a mesh or grid arrangement that offers the advantage of point-to-point communications without a hub. This arrangement results in reduced transmission delay. Because the need for a master earth station is eliminated, total capital outlay can be lower for small networks.

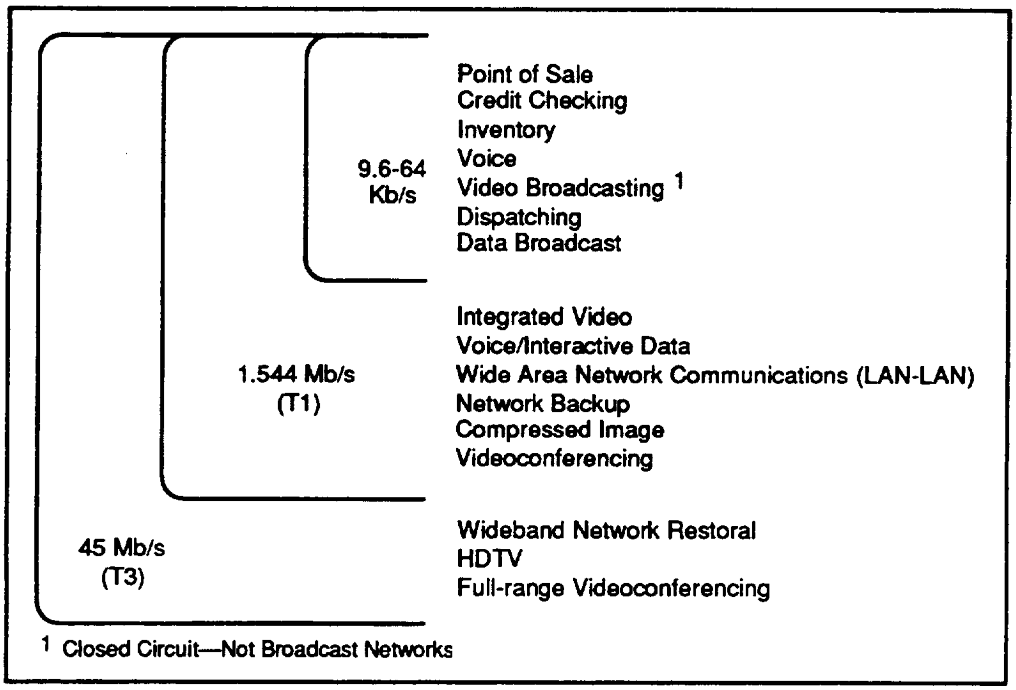
VSAT communications can be accomplished in several ways. One method now used is Frequency Division Multiple Access (FDMA). In this method each node has its own frequency assigned (i.e., a signature). This method requires sophisticated computing capability at each remote terminal to handle the filtering process, and to maintain the frequency assignments for each terminal. This method uses frequency spectrum inefficiently because no two terminals can have the same frequency signatures, thereby limiting the number of terminals in a network to the number of channels.

Another method uses TDMA to allow multiple access to a single satellite channel. The satellite channel is divided into defined timeslots and transmission takes place based on a calculated probability of collision between two terminals. When a station has completed its transmission, a number of slots are defined (N). Each station that wants to access the channel selects a random slot in the range 1 to N and starts transmission at that time. If a collision occurs, the channel acquisition phase must be restarted. The value of N depends on the observed frequency of collisions between stations. This method is highly reliable and avoids the inefficiencies of FDMA methods (Telecommunications January 1990).

VSAT network technology has three major advantages. VSATs can provide economical private communications with a high degree of reliability; they can function over geographically dispersed locations; and they are easily reconfigured or expanded. In addition, VSAT costs are easily predictable over the useful life of the equipment and operation and maintenance are simplified due to the limited number of network components.

A wide range of telecommunication services is possible with VSATs including data broadcast, point-of-sale, banking and financial services, credit verification, centralized stock control, centralized travel reservation, and pipeline monitoring and control. Figure 4-41 shows that as technology advances and the bandwidth capability of VSATs increases, a greater number of services can be supported. At T1 rates, integrated video, video-conferencing, and network backup applications become feasible. At T3 rates (45 Mb/s), wideband network restoral, HDTV, and full-range video conferencing become possible.

FIGURE 4-41
Potential VSAT Services Increase With Bandwidth



Source: Booz-Allen & Hamilton

Present data traffic for VSATs consists of very low rate, bursty, transmission; high speed, bulk data transmission; and LAN-to-LAN transmissions.

Low rate, bursty transmission

Interactive and Query/Response are the major transaction types that fit into this category. Interactive transactions have a relatively short duration, are small in size, must be highly accurate and have a high priority; examples are file edit or record interchange between computers. Response times for interactive transactions are relatively short, 2 to 5 seconds.

Query/Response transactions are different from interactive transactions because the amount of information in the communications varies according to the nature of the transaction. Also, the required response time for a Query/Response transaction may range from a few seconds in the case of an airline reservation to several hours for retrieving an archived message. Query/Response transactions are very common in business management information systems, inventory management, and travel reservation systems.

Bulk data transactions

Bulk data transactions are communications of large amounts of data in either character or binary format. Bulk data can be described as image data or absolute data. Image data are formed by the digitization of images such as facsimile and video, and absolute data are defined as an exact representation of the information in digital form. Image data and absolute data differ in their tolerance of transmission errors. Image data can generally be transmitted without error correction protocols whereas absolute data must have strict error control protocols to ensure error-free transmission (Chakraborty May 1988).

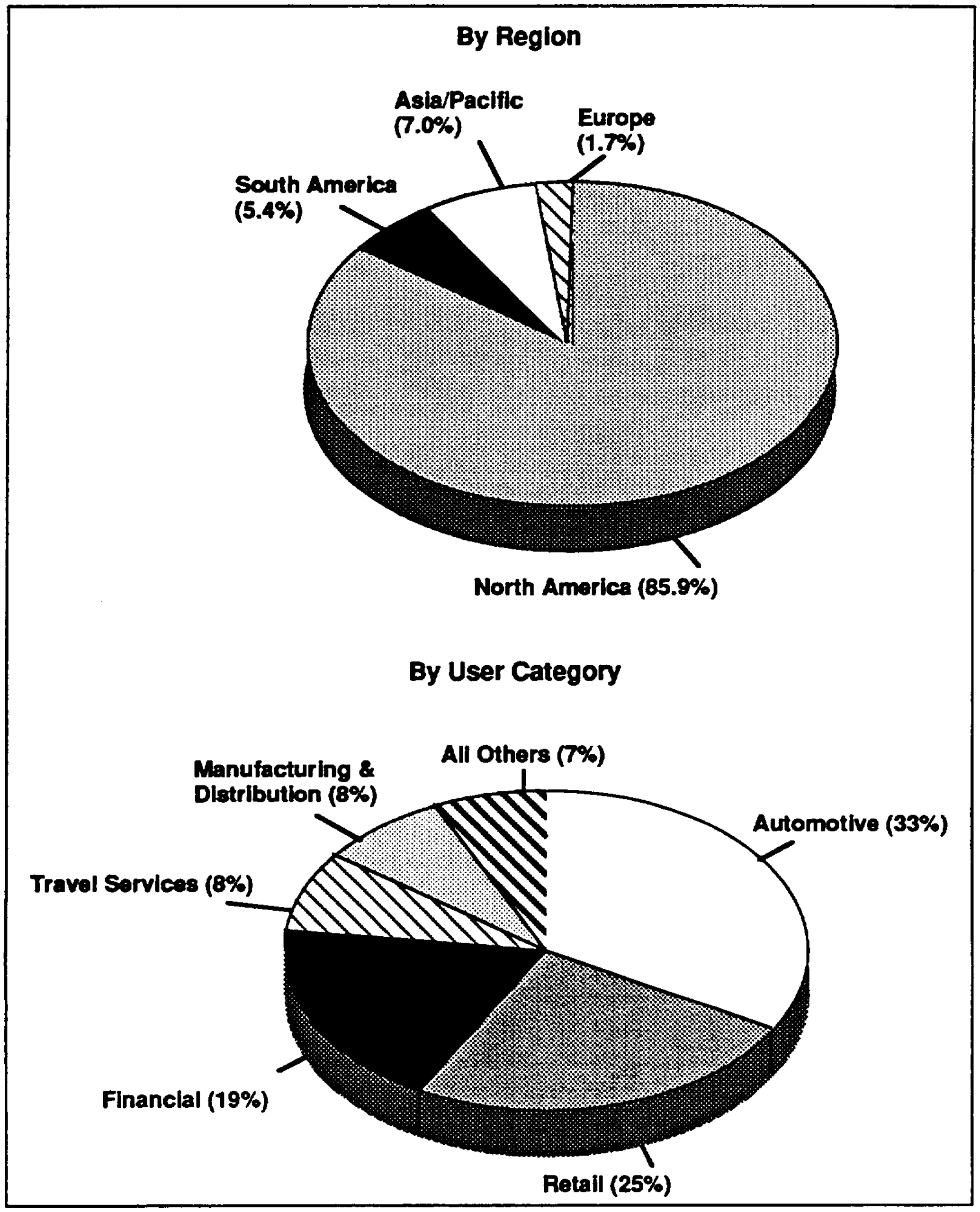
LAN-to-LAN transmission

An important use of VSATs in the future will be to bypass Local Area Network (LAN) gateways to directly transport LAN-to-LAN communications. Typical VSAT interLAN communications are done through gateways that convert the LAN protocol to a WAN protocol. These gateways interface at very low speeds relative to both the capability of the VSAT and the transmission rates of LAN traffic. New integrated LAN interfaces provide direct access to the full inbound and outbound capacities of the VSAT, which results in increased performance and reduced capital outlays. The high-bandwidth capability of VSATs will become a more attractive alternative for LAN managers as the higher transmission rates of Fiber Distributed Data Interface (FDDI) and the increased computing power of workstations increase the demand for high-speed interLAN communications. Reliability is also enhanced by the removal of an extra network component.

In addition to eliminating an expensive gateway device in the network architecture, VSATs also replace the need for a router. The star configuration of a VSAT network provides a single path for communications. Traffic is sent from the remote terminal to the hub where the traffic is terminated or sent to another remote terminal via an intelligent interface that automatically learns the addresses on the locally attached LAN and then switches traffic to the appropriate node. Configuration and setup are also simplified for networks with many remote locations by eliminating the router (Cacciamani and Polti November 1991).

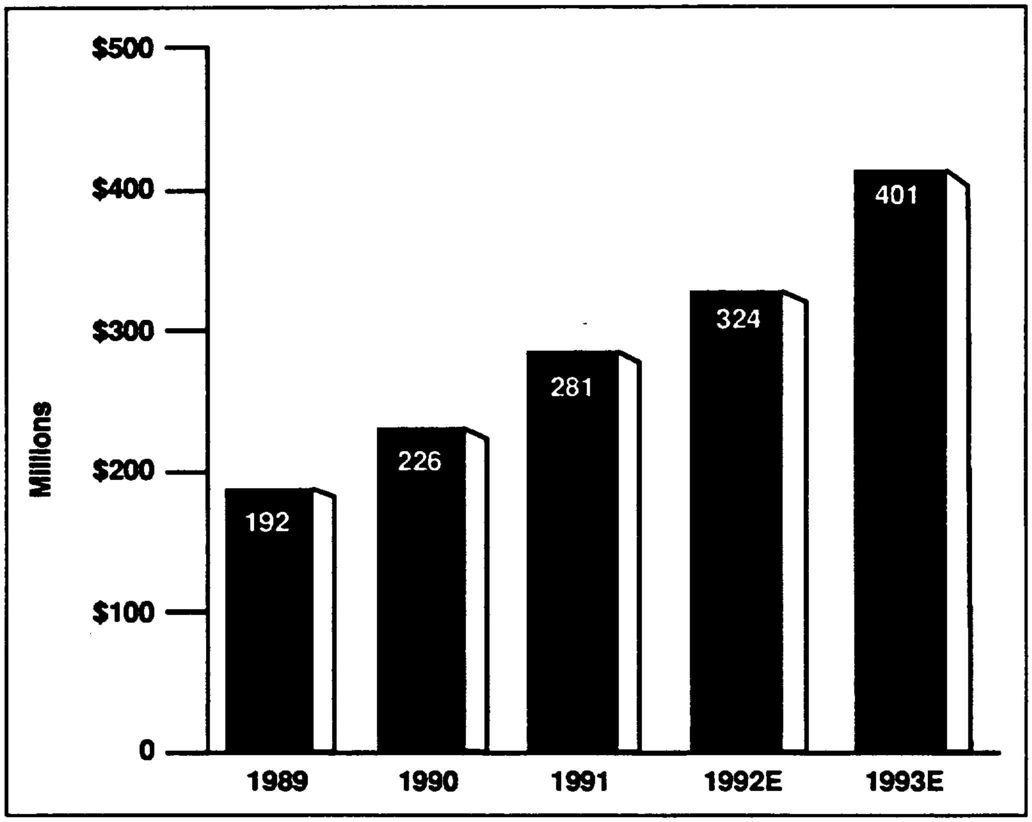
4.3.1.1 Status. The VSAT equipment market has grown rapidly in recent years with its installed base now exceeding 80,000 terminals. Figure 4-42 shows the distribution of the VSAT base by industry category. As can be seen from this figure, a majority of these terminals are used in the retail, automotive, and financial services industries of North America (RKM Associates 1991). Figure 4-43 presents the estimated total equipment revenues for 1989 to 1993. This figure shows that total equipment revenues increased at a 35 percent compound annual growth rate from 1989 to 1991 and are estimated by the Yankee Group to have exceeded $280 million in 1991 (Boeke February 1992; International Data Corp. April 1992). Growth is being fueled by the addition of new networks and the expansion of existing networks.

FIGURE 4-42
Installed 1991 VSATs



Source: RKM Associates, International Data Corp.

FIGURE 4-43
VSAT Equipment Revenues



Source: Yankee Group

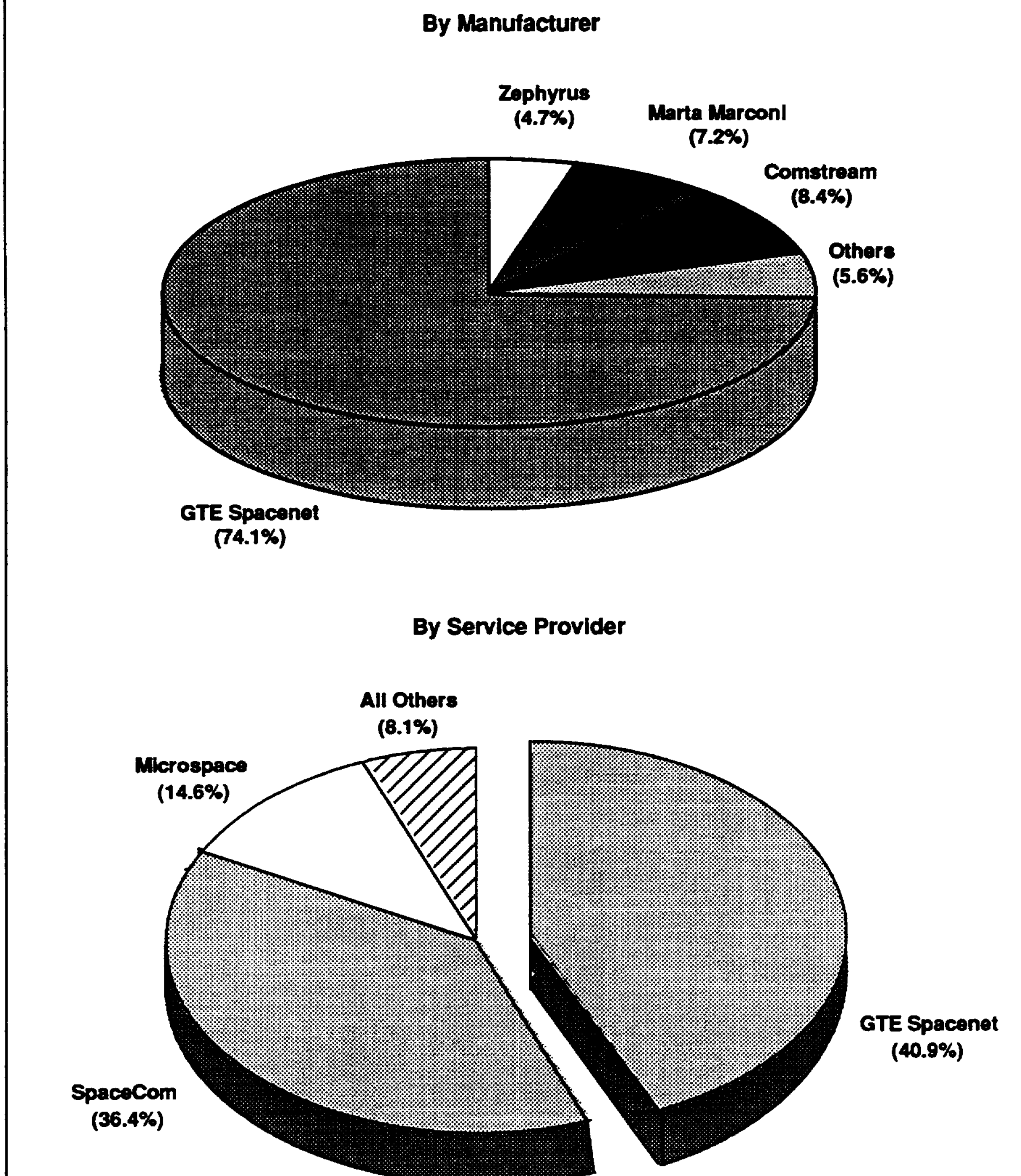
The VSAT market is dominated by a few large equipment manufacturers and service providers. Figure 4-44 presents the market shares for data broadcast receivers by manufacturer and by service provider. As figure 4-44 shows, GTE Spacenet is the largest manufacturer of data broadcast receivers with almost 75 percent of the installed base. In addition, GTE and SpaceCom are the dominant service providers in this market segment with the two firms accounting for 77 percent of the total installed base. Figure 4-45 presents the interactive (two-way) VSAT market share by manufacturer and service provider. As this figure demonstrates, the interactive (two-way) VSAT market is dominated by Hughes Network Systems, which holds more than 50 percent of the equipment market, and GTE Spacenet, which holds more than 50 percent of the market for VSAT services (RKM Associates 1991).

4.3.1.2 Plans. Many users are expanding their VSAT networks. Large networks such as those operated by General Motors, Chrysler, and Chevron plan to add several thousand terminals to their existing networks in the next few years (Marek August 1991).

The backlog of orders for VSAT terminals is presented in figure 4-46 (Bull 1991). The backlog of orders for interactive terminals is almost twice the installed base, indicating that the increased functionality of two-way terminals is being widely accepted by new users. Although the pending orders for data receive-only terminals are also quite large, these orders exceed the installed base by a smaller percentage. Evidence of VSAT market saturation is presented in figure 4-47.

This figure shows that the growth of new VSAT systems installed declined 15 percent in 1991 (Marek August 1991), indicating that the VSAT market may be reaching saturation in the next few

FIGURE 4-44
Market Share for Data Broadcast Receivers (Installed) (1991)



Source: RKM Associates

FIGURE 4-45
Market Share for Interactive Terminals (Installed) (1991)

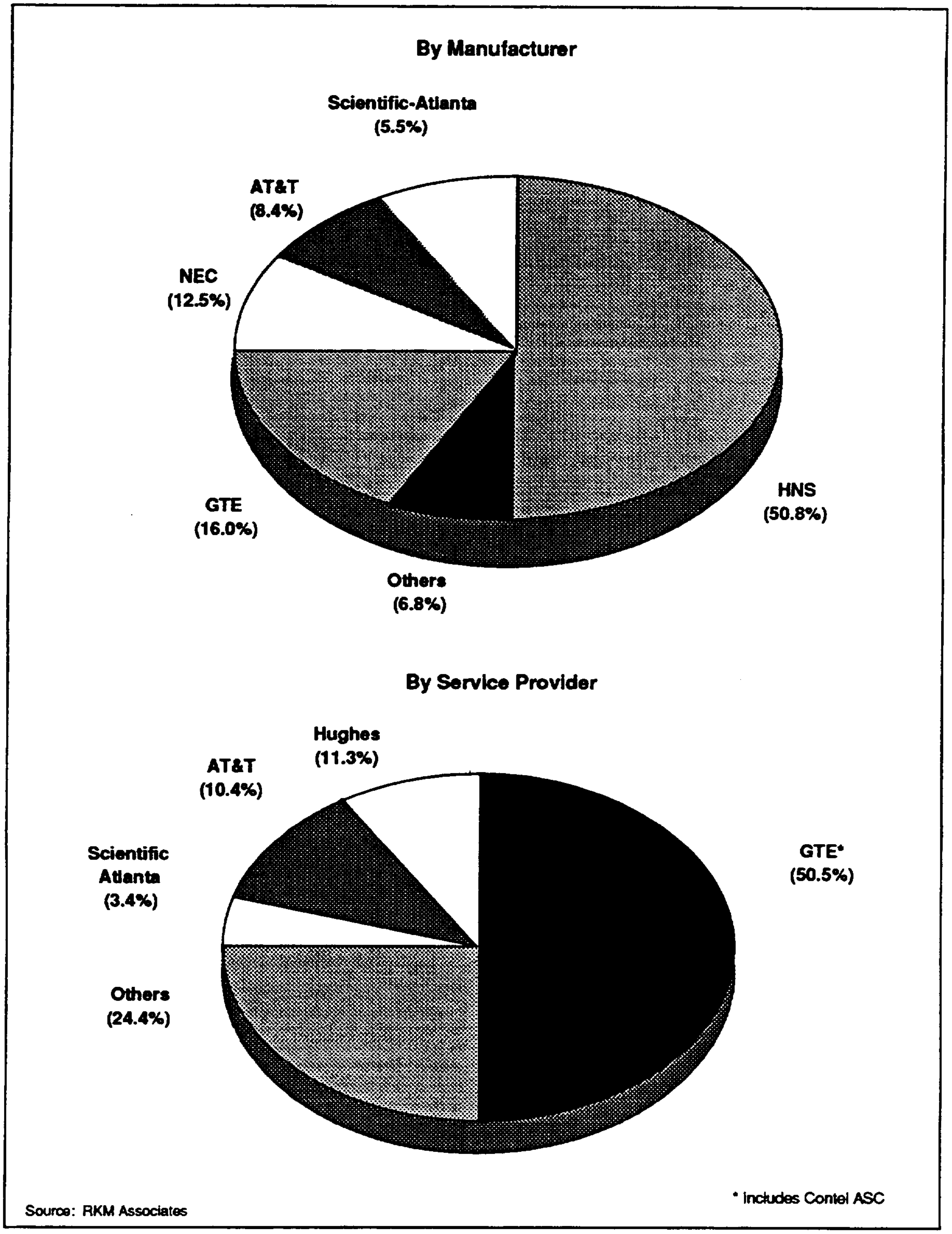


FIGURE 4-46
Worldwide VSAT Market (1991)

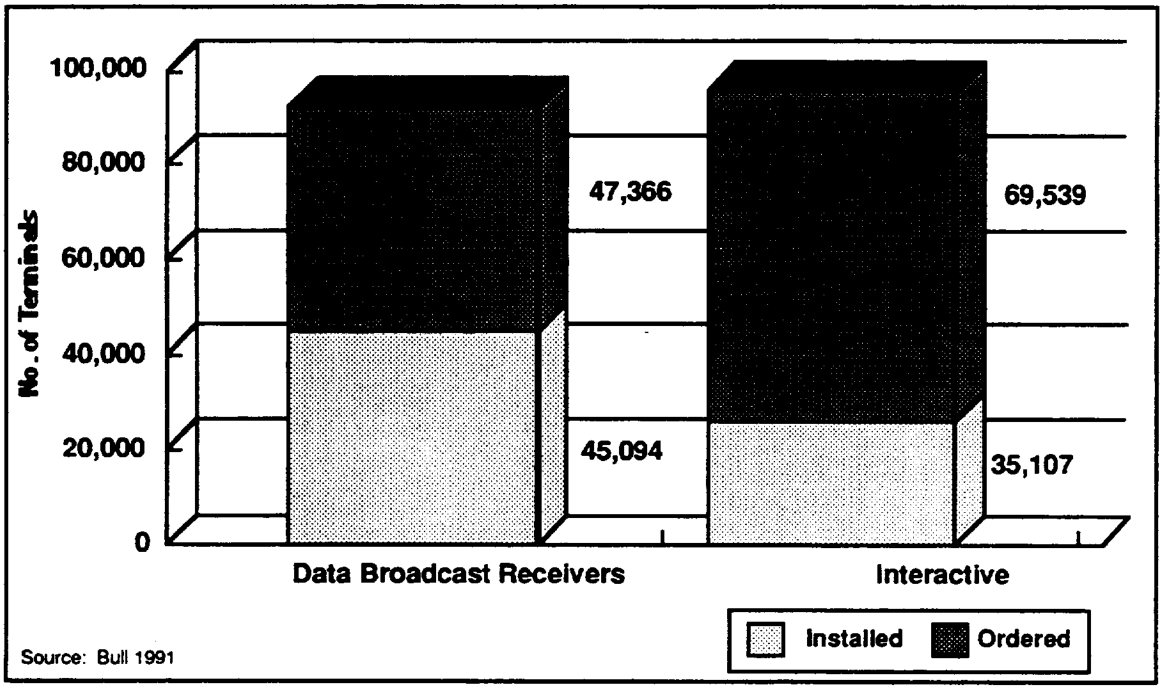
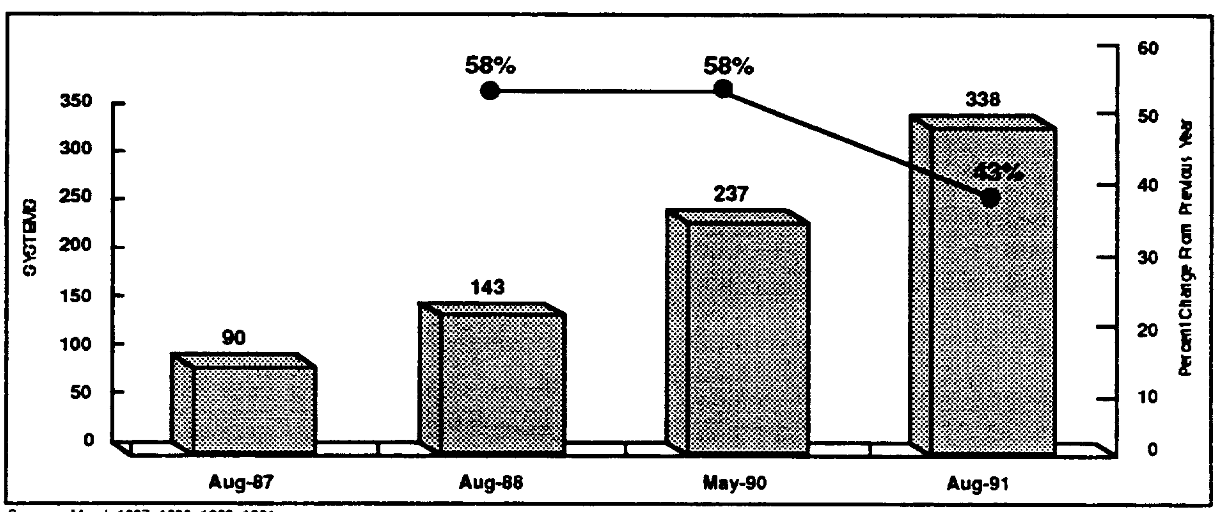


FIGURE 4-47
Systems in Operation



Sources: Marek 1987, 1988, 1990, 1991

years as these orders are filled. The total of the installed base and the backlog of terminals is nearly 50 percent of the estimated total market for VSATs of 400,000 terminals (Bennet August 1988). As competition increases from other forms of communications technology, such as software defined networks, VSAT manufacturers will find that cost leadership, in terms of airtime and capital outlay for hardware, will become the key drivers of continued market growth.

Mesh VSAT

As discussed earlier, connecting VSAT terminals in a grid or mesh network has several advantages. Mesh-connected VSATs offer users all the benefits of traditional star configuration networks without the problem of 2-hop transmission between remotes. Mesh VSATs allow direct instantaneous communications between any two terminals in the network. Despite the obvious benefits of mesh technology, only one manufacturer has introduced a mesh VSAT product, Spar Communications (U.S. Department of Commerce 1991). Several manufacturers of earth station equipment offer mesh connected systems, but only with antenna sizes larger than 2.4 meters. Such a large antenna entails much larger capital expense, usually on the order of a master earth station, and therefore is not cost-effective for large numbers of locations. (It should be noted that some manufacturers maintain that the higher cost of large antennas is due to low demand rather than intrinsic cost [Spar Communications].) Because we are concerned with applications with the potential to become a major user of space communications infrastructure, we do not consider this type of earth station in our analysis.

Two interrelated factors have limited the introduction of mesh VSAT: (1) the significant technological barriers that must be overcome to achieve mesh connectivity; and (2) the high cost of a mesh terminal, which is still greater than $50,000 for a Spar VSATplus™ terminal. The available beams that cover the continental United States have limited effective isotropic radiated power (EIRP). This limited EIRP constrains the transmission speeds possible to small receiving antennas. As a result, the electronics required to achieve mesh connectivity using existing transponders is still very complex.

The Spar product creates mesh connectivity by building network management capabilities into one of the VSATs. The terminal has a relatively high-bandwidth capability (T1/E1), operates at Ku- or C-bands, and is compatible with all presently orbiting satellites. Spar plans to introduce a smaller mesh terminal for use with multiple-spot-beam satellites in 1993.

Spar Communications is targeting the sale of its mesh VSAT products to address the following five niche markets:

- Backup communications for public switched network carriers
- Transmission of CAD/CAM images
- Communications for commercial and government users with extremely remote sites, such as the Department of Interior and off-shore oil exploration component
- Connection of companies' foreign offices where the public infrastructure is inadequate or unavailable
- Video conferencing and broadcasting.

4.3.1.3 Deployment. VSAT market growth is expected to continue for the next 5 years with estimates of new system installations ranging from 10 to 20 systems per year (U.S. Department of Commerce 1991). As discussed earlier, the future reduction in new system installations indicates that the VSAT market may be maturing. Future growth in VSAT sales is expected to be driven by overseas markets, where VSATs are now being implemented, and from the broadening of the market base to smaller user groups in the United States.

Broadening the U.S. market base entails continuing to reduce the cost of VSAT service to a point where it is price competitive with terrestrial networks. The deployment of optical fiber provides significant economies of scale to the public switched network operators and allows them the flexibility to reduce their prices. Newly instituted price-cap regulation also creates incentives for the operators to reduce their cost structure by restricting the allowable increases in tariffs to less than the rate of inflation. A broadening of the market would require the VSAT industry to make continual advances in technology to stay cost competitive.

Another approach to maintaining growth in the VSAT industry is to differentiate the VSAT from other communication media by providing enhanced functionality. Increased bandwidth capability, reduced rain-fade effects, reduced antenna size, and imperceptible transmission delay are a few examples of improvements that will have value to future VSAT users. These are the goals of mesh VSAT research being conducted through several programs at NASA. Rather than addressing the traditional VSAT market where communications are required with a central data base on an intermittent basis, mesh VSATs would compete directly with "bandwidth on demand" switched services that terrestrial carriers are introducing such as frame relay, SMDS, and eventually, BISDN (Spar Communications). Mesh VSAT will be attractive to users who must communicate between several remote locations, rather than with a central database, and that require greater than T1 (1.544 Mb/s) transmission speeds. Voice-only services or data rates lower than T1 will be more economically served by the PSN. However, it is unlikely that gigabit transmission speeds will be achieved with VSATs because the required EIRP would cause significant interference with other users or would require unusually large and expensive antennas. Therefore, mesh VSATs will likely have an effective transmission capability up to a DS3 (45 Mb/s). (Theoretically, mesh VSATs that are designed to work with NASA's ACTS technology could have much higher bandwidth capability, on the order of 2 GHz.)

Mesh VSAT could broaden the VSAT market beyond the traditional sectors of retail trade, banking/finance, insurance, and manufacturing to areas of health care, business services, utilities, and governmental organizations. Figure 4-48 shows the potential mesh VSAT user industries and their likely communications needs. Manufacturers, government agencies, and business services would be the majority of mesh VSAT users; video conferencing and high-definition image transfer would be the most popular communications needs.

For instance, government agencies, such as the Department of Interior, may find that mesh VSAT is an attractive way of providing communications to remote sites where infrastructure may not be easily available. Other agencies could find network backup and restoral and communications with foreign offices as attractive uses of mesh VSATs. In addition, advertising agencies (business services) could use mesh VSATs for high-definition image transfer of layouts. Utilities may use mesh systems to monitor power generation and transmission.

FIGURE 4-48
Potential Uses of Mesh VSAT

	Network Backup	High-Definition Image Transfer	Remote Communication	Foreign Private Network	Video Conference	Traditional VSAT Services
Government	✓		✓	✓	✓	
Retail Trade					✓	✓
Transportation						
Banking/Finance	✓			✓	✓	✓
Insurance		✓				✓
Utilities	✓		✓			
Manufacturing		✓		✓	✓	✓
Education						
Health Care		✓			✓	
Business Services		✓	✓	✓	✓	
AG/Mining/Constr.			✓			

Source: Booz-Allen Analysis

Regulatory

Regulatory control is a major factor that affects the acceptance of VSAT technology. In the United States the licensing of entire systems (Ku-band only), rather than each terminal, reduced the administrative bureaucracy involved in building systems. This procedural change favored the implementation of Ku-band VSATs over C-band VSATs, which still require licensing each station and the certification of noninterference with other users of that band. Other regulatory factors, such as the pricing freedom of domestic satellite operators that allows VSATs to maintain a competitive edge over terrestrial private networks, also enhanced the attractiveness of implementing VSAT systems.

4.3.1.4 Costs. The price of satellite services is affected by the cost of key system components. System components can be grouped into space and ground segments. Space segment costs depend on the following:

- Availability of bandwidth on transponders
- Transponder frequency (i.e., C, Ku, or Ka bands)
- Cost of building the satellite
- Cost of launching the satellite
- Operations costs (tracking, telemetry, and control station and other overhead costs).

Terrestrial segment costs depend on the following:

- VSAT hardware
- Installation costs
- System license fees
- Operation and maintenance.

Orbital costs are constrained by several interrelated supply factors: availability of launch vehicles, orbital spacing, usable life, transponder population, and on-board power. The supply of terrestrial equipment is only constrained by the production capacity of the manufacturers.

The first orbital constraint is the availability of launch vehicles for placing satellites into orbit. Most providers of launch vehicles have large backlogs of deliveries. This requires significant lead time in adding capacity. Therefore, satellite circuit capacity must be sufficient when placed into orbit to allow for the growth in demand. Satellites often have excess capacity for several years because of this constraint.

The second orbital constraint is the reduced orbital spacing mandated by the FCC. In 1983, the Reduced Orbital Spacing decision was adopted by the FCC to address the increased demand for orbital slots. In this decision the FCC ruled that orbital locations should be reduced from a 4-degree spacing to 2 degrees. This mandated that all new C and Ku-band satellites must satisfy the 2-degree spacing and that all transmit earth stations in operation after January 1987 must comply with new, more strict sidelobe interference specifications (Krauss April 1991). The FCC subsequently allowed nonconforming earth stations to continue operations by notifying the FCC before December 31, 1986. Although reduced orbital spacing creates more available orbit locations, the problems resulting from sidelobe interference adds to the costs of the satellite and its associated earth station equipment.

The usable life of a satellite is the third orbital constraint. This is determined by the amount of on-board fuel required to maintain orbit integrity. Orbital life is typically 10 years, although some satellites have exceeded this. When on-board fuel is exhausted, the satellite's orbit decays, causing it to enter the earth's atmosphere and disintegrate. By this time, most of the transponders are usually inoperable.

The number of on-board transponders is the fourth orbital constraint. Because traditional "bent-pipe" satellites have a fixed number of transponders, significant capacity on a satellite must be presold for the satellite to be an economically viable investment.

The last orbital constraint is on-board power. The on-board power of satellite transponders limits EIRP and affects many design parameters such as antenna size, on-board power storage and generation, and beam coverage area. Improvements to solar cell array and storage battery technologies are crucial to improving on-board power generation. Spacecraft with greater transponder power will enable greater transmission speeds for existing VSAT systems, and will also permit the use of submeter antennas in future VSAT designs while maintaining high data transmission speeds.

Technology must develop solutions for VSAT to overcome these constraints and maintain its cost competitiveness. In fact, VSATs have a history of rapid technological innovation (Mazer and Halversan November 1989) as presented in figure 4-49. Improvements in microprocessors such as Very Large Scale Integration (VLSI) will enable VSAT and spacecraft designs to integrate many of the functions of a hub station. The development of submeter antenna dishes will allow indoor installation of VSAT stations. By removing the VSAT from weather hazards, the expense of manufacturing and maintaining terminals can be greatly reduced. Furthermore, indoor installation also opens markets for VSATs in places where local governments have restrictions on the outdoor mounting of dish antennas.

FIGURE 4-49
VSAT Technology Developments

1980	–	First widespread commercial use of VSAT (one-way broadcast)
1984	–	First widespread interactive VSAT
1985	–	First voice applications
1986	–	First asynchronous data applications
1987	–	First use of non-penetrating VSATs
1988	–	First point-to-point applicatons First packet-switching applications Enhanced video teleconferencing Enhanced voice capability First T1 applications
1989	–	Ultra Small Aperature Terminal (USAT) Solar powered VSAT (Solsat)
1990	–	HNS introduces .74 m VSAT GTE introduces compact hub
1991	–	SPAR introduces first T1-capable Mesh VSAT
1993	–	First spot-beam-capable Mesh VSAT systems available

Source: Satellite Communications, Booz•Allen Analysis

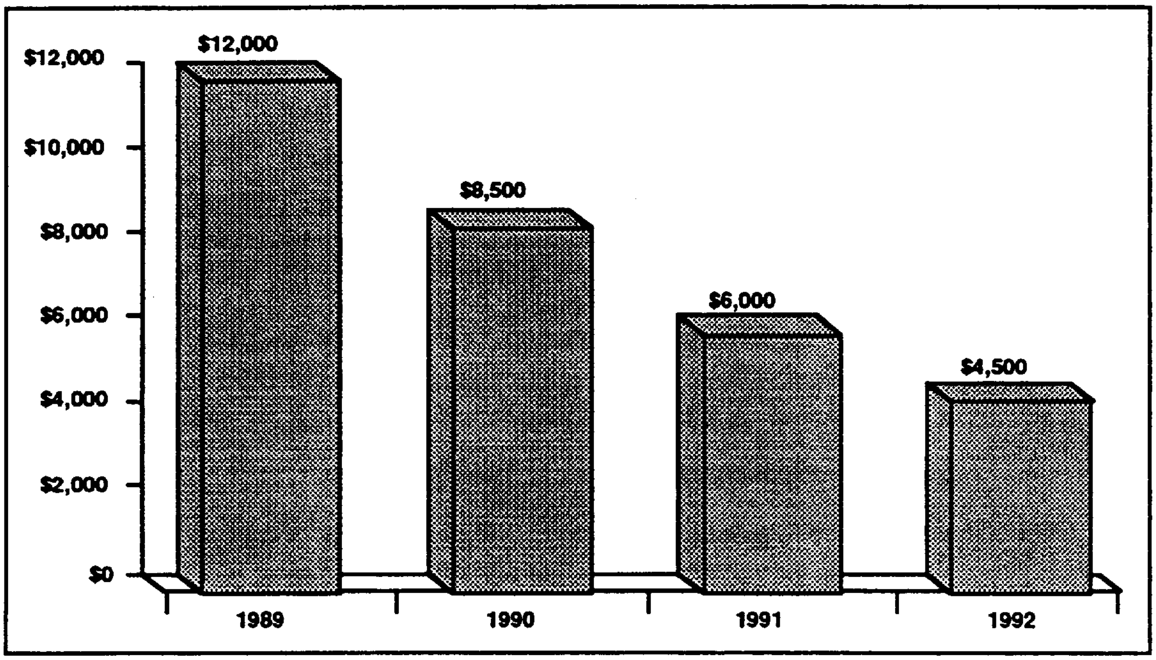
In addition, improvements in frequency spectrum management techniques and frequency re-use methods will increase the capacity of existing satellites. Use of TDMA and Code Division Multiple Access (CDMA) allows many users to share the same frequencies during transmission. Deployment of multiple-spot beam satellites, such as Orion, promotes frequency management efficiency through the re-use of frequencies in nonadjacent cells. Utilization of these techniques is expected to add significantly to the efficiency and the economic operation of satellite systems.

Hardware Costs

The capital cost of a VSAT is declining due to two factors: developments in technology and competition. As discussed earlier, VSATs have a history of rapid innovation. An example of continuing technological development is the planned deployment in early 1993 of NASA's Advanced Communications Technology Satellite. The technology developed by NASA's ACTS program represents significant advances in satellite technology, such as transponder design, on-board processing, and spot beams. These technologies have the potential to drastically reduce the cost of earth stations while simultaneously providing increased bandwidth capability and terminal portability. Both of these trends are required for sustained growth in the VSAT market.

Competition also has a profound effect on the price of VSAT equipment and service. The level of competition in the VSAT market has increased in recent years as evidenced by the concentration of market shares among a few VSAT manufacturers and service providers. Competition with alternative service providers, or Value-Added Networks (VANs), also places pressure on industry participants to maintain price competitiveness by reducing their costs. As shown in figure 4-50, prices for 9.6 kb/s terminals have declined on average more than 25 percent per year since 1989 (Schwartz 1992; Korzeniowski February 1991; Brown April 1991). Other segments of the VSAT market, such as hub earth stations and T1-capable terminals, have experienced similar trends. For instance, 5 years ago hub earth station would cost on the order of $1.5 to 2 million where now prices are easily under $0.5 million.

FIGURE 4-50
VSAT Capital Cost for 9.6 kb/s Terminals



Source: VSAT Vendors; Brown 1991; Korzeniowski 1991

As figure 4-51 illustrates, mesh VSAT systems are very expensive relative to hub systems on a per-terminal basis. However, only one manufacturer presently offers a mesh VSAT product and it has only been available for less than a year, indicating that mesh VSAT systems are still in the product introduction stage of the product life-cycle where customer awareness is low. The high price of a mesh VSAT confines its market to a small niche of users who can realize increased cost effectiveness because the cost per mesh VSAT is lower than other alternatives.

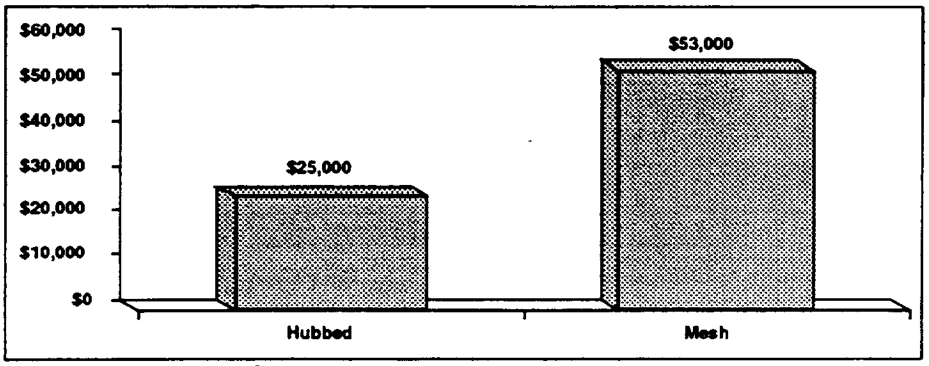
Comparing Costs

When evaluating network alternatives, VSAT generally competes with terrestrial multi-drop networks. With a terrestrial multidrop network, the cost components for each drop location consist of the following:

- Connection charges to the central office (CO) for every drop location

- Local loop charges from the customer's premises to the CO
- Long-distance line costs that are shared by all of the drop locations on the same multi-drop line. (Sharma February 1989).

FIGURE 4-51
Capital Cost of a T1 VSAT



Source: SPAR Communications, DataPro

The key cost components of a VSAT network are the VSAT stations, the hub, and the satellite transponder time. Figure 4-52 explains the methodology for evaluating these alternatives.

FIGURE 4-52
VSAT and Terrestrial Cost Relationship

Monthly Cost/Drop Location

MC	=	(C1 + C2 + C3 + M)*(Capitalization Factor) + (L1 * LL + L2) + (X1 * A + Y1)/N
MC	=	Monthly cost
C1	=	One-time charge per central office connection.
C2	=	One-time charge for access coordination per central office connection.
C3	=	Average one-time installation charge per local loop.
M	=	One-time capital cost/modem.
Capitalization Factor	=	Based on a 5-year amortization at 10% ROR = .0212
L1	=	Monthly per mile average cost per local loop.
L2	=	Month average fixed cost per local loop.
LL	=	Average length per local loop.
X1	=	Monthly per mile cost per long-haul line (varies with mileage band.
A	=	Average miles per long-distance line = (Average drops/line-1) * (Average miles between drops)
Y1	=	Monthly fixed costs per long-distance line (varies with mileage band).
N	=	Number of drops/line.

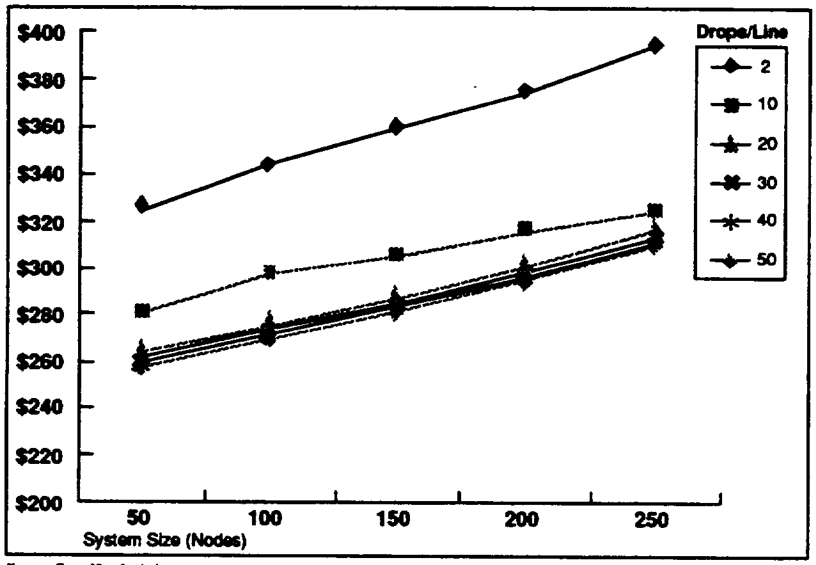
Monthly Cost/VSAT Location

MC	=	(X + H * M / N) * (Capitalization Factor) + (S1 + S2 * K) / N
X	=	Installed cost per VSAT
N	=	Number of VSATs
H	=	Installed cost per hub
M	=	Number of hubs necessary to support N VSATs
Capitalization Factor	=	Based on 5-year amortization at 10% ROR = .0212
S1	=	Transponder cost per month for inbound VSAT-hub carrier (assumes one carrier of adequate bandwidth shared by all VSATs)
S2	=	Transponder cost per month for outbound hub-VSAT carrier
K	=	Number of outbound carriers of a specific bandwidth necessary to support N VSATs = INT [N / (Number of VSATs per outbound carrier) + 1]

Source: Sharma 1989

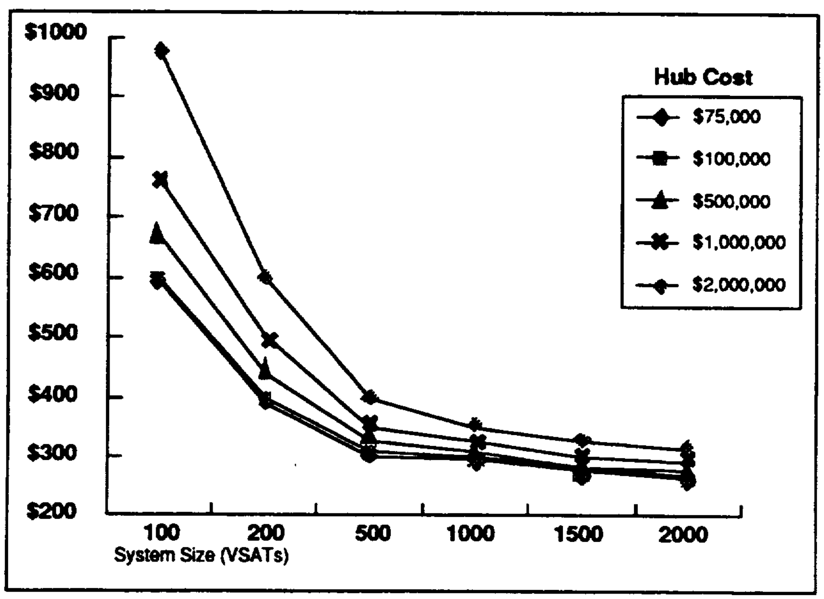
For a terrestrial multidrop network, the cost per location varies with the average length of lines and the number of drops per line as illustrated in figure 4-53. Figure 4-54 demonstrates the cost relationship for VSAT networks by using the same methodology. From this analysis, VSAT cost per month drops as the number of terminals in the network grows. For large networks the major cost component is the VSAT stations; for small networks the most significant expense is the space segment.

FIGURE 4-53
Cost Relationship for Terrestrial Multidrop Network



Source: Booz-Allen Analysis

FIGURE 4-54
Cost Per VSAT Per Month



Source: Booz-Allen Analysis

The methodology for comparing satellite and terrestrial systems is presented in more detail in Section 6.0 where it is used to determine the amount of telecommunications traffic that can be captured by hub and mesh VSATs.

4.3.1.5 Traffic. Voice is not a major portion of overall VSAT traffic and today accounts for only 4 percent of the total VSAT usage (Simo November 1990). Video, although presently only 5 percent of total VSAT traffic, is expected to grow rapidly as videoconferencing becomes more popular. The remaining traffic type—data—will be driven by uses such as Electronic Data Interchange, Electronic Funds Transfer, and data-intensive services within closed user groups.

VSAT traffic projections through the year 2011 are provided in figure 4-55. These projections are based on anticipated traffic levels developed in Section 2.0, extrapolation of current VSAT market trends, and analyses of closed user group traffic ratios. As indicated in the figure, VSAT traffic will include facsimile, e-mail, terminal operations, EFT, EDI, educational television, and business television traffic types. Based on Booz·Allen analysis, the potential VSAT traffic growth is projected to steadily increase as a result of the overall trend for increased data and image traffic through the time-frame of this study period.

FIGURE 4-55
VSAT Traffic Projections

DSOs	DSO Units	Busy Hour Traffic Projections 1991	1996	2001	2006	2011	Traffic Allocation Factor *
Voice							
MTS (Business)	DSOs (10^6)	-	-	-	-	-	
MTS (Residential)	DSOs (10^6)	-	-	-	-	-	
Private Lines	DSOs (10^6)	-	-	-	-	-	
800	DSOs (10^6)	-	-	-	-	-	
900	DSOs (10^6)	-	-	-	-	-	
Private Networks	DSOs (10^6)	-	-	-	-	-	
Data							
Facsimile	DSOs (10^3)	62	130	36	8.8	11.5	0.4
E-Mail	DSOs (10^3)	0	0.40	19.0	74	120	0.9 – 0.4
Terminal Operations	DSOs (10^3)	3.3	5.9	14.5	21	30	0.8
On-Line Info. Services	DSOs	-	-	-	-	-	-
EFT	DSOs (10^3)	0.100	0.30	0.50	0.59	0.61	0.1
EDI	DSOs (10^3)	0.145	0.35	0.70	0.80	0.83	0.5
Video							
Network Broadcast	DSOs (10^3)	-	-	-	-	-	
Cable TV	DSOs (10^3)	-	-	-	-	-	
Educational TV	DSOs (10^3)	-	0.73	4.3	8.3	14.0	0 – 0.5
Business TV	DSOs (10^3)	440.0	155	105	105	78	1 – 0.4
Viewer Choice TV	DSOs (10^3)	-	-	-	-	-	

Source: Booz·Allen Analysis
* Traffic allocation factors are the fractions of total traffic that represent potential VSAT traffic

4.3.2 Direct Broadcast Satellite

DBS is a term used to describe a satellite delivery system designed to provide video, audio, and data services directly to the end-user. One distinguishing characteristic of DBS is the relatively high power of the broadcast signal, which allows the use of relatively small receiving antennas. Another characteristic of DBS is that service can be provided directly to the end-user rather than being relayed via a secondary transmission medium, such as terrestrial transmitters or cable distribution networks.

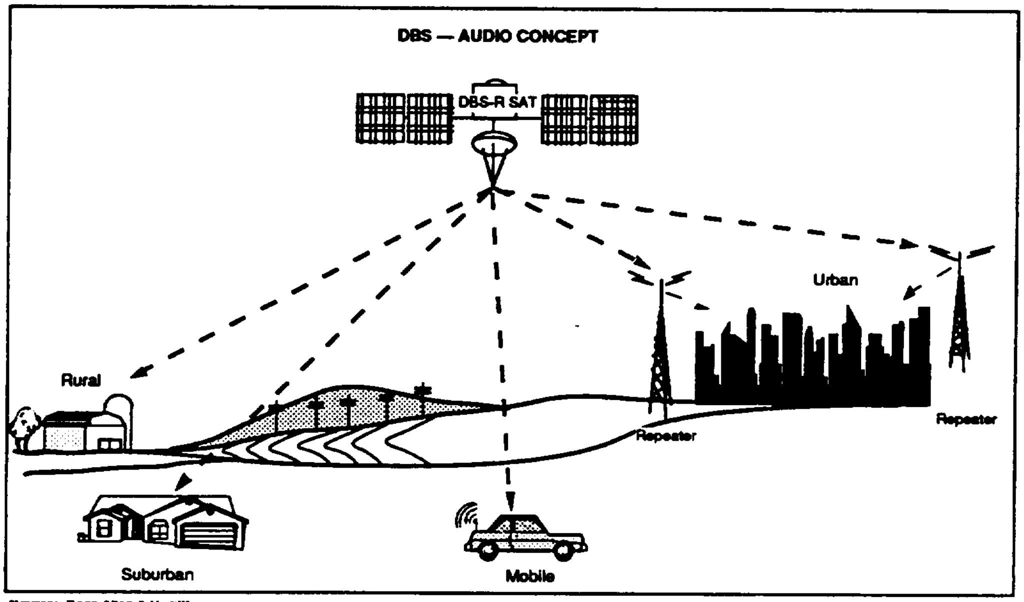
DBS, after COMSAT's failed in the early 1980's, has recently begun to receive renewed interest in the United States as both video and audio service providers examine the potential of DBS as a delivery system for their products. This section will highlight the primary applications of DBS, the current status of DBS systems, industry plans for DBS development, a deployment schedule of DBS systems and the externalities impacting that schedule, cost estimates for DBS systems, and an estimate of DBS traffic through the year 2010.

A key design issue in DBS-Audio is the optimization of the system's space and ground segments with the objective to reduce end-user product costs. Because DBS-Audio will be competing with well-established broadcast services, the final cost to the consumer and the robustness of services will be critical factors in the final success of DBS-Audio. Other success factors include the development of advertising markets and the definition of the proper programming mix.

DBS Audio

Broadcasting companies are showing a heightened interest in DBS-Audio as a viable method for program delivery. Advantages of DBS-Audio include regional and national coverage capabilities, a full range of service quality from AM monaural to CD stereo, and consistent reception quality. From a technical standpoint, DBS-Audio systems can provide multiple channels over a single transponder. Figure 4-56 illustrates a typical DBS-Audio configuration. (It should be noted that in certain urban settings repeaters are used to mitigate interference effects from buildings.)

FIGURE 4-56
DBS Audio Concept



Source: Booz-Allen & Hamilton

DBS Video

It has been a long-held view of the FCC that direct satellite broadcasts of television signals could serve as an additional mechanism for meeting public communications requirements. In 1980 the FCC authorized the construction of domestic DBS-Video systems and began accepting applications. Early applicants to the domestic DBS market did not meet with immediate success. Soon after the FCC announcement, COMSAT initiated its plans for a domestic DBS satellite system. The original plan called for four 200W per channel satellites to provide the four U.S. time zones with three TV channels. With the increased programming available from a burgeoning cable industry, it quickly became obvious that the COMSAT system was too costly and delivered too few programming options. COMSAT attempted to modify its approach in 1983 to be more in conformance with the standards set by the Regional Administrative Radio Conference (RARC). This shift came too late and the COMSAT system never succeeded in obtaining the necessary financing and programming. Another factor that contributed to COMSAT's lack of success was its inability to secure financing for the manufacture and distribution of receiving equipment. Other interested parties in the DBS-Video market included USCI, Hubbard Broadcasting, and Direct Broadcasting Satellite Corporation. Each of these ventures suffered from a similar range of technical and financial problems. Additionally, competition from TV network affiliates and cable systems contributed to the initial failure of DBS-TV systems.

In spite of these failures there is an example of direct broadcast video success in the United States. In 1975 Home Box Office (HBO) began transmitting movie programs to cable operators using an RCA satellite. One year later Ted Turner's Atlanta television station began broadcasting nationally and soon dozens of television services were operating through satellites. While this type of satellite broadcast was geared toward cable systems and network affiliates, consumer demand and improved technology quickly spurred the home satellite dish industry. Three- to four-meter dishes capable of bringing satellite programming directly into the home began appearing, particularly in areas without access to cable television. These units receive signals from 15 low-powered geostationary satellites. Today there are more than 3 million home TVRO terminals in the United States, with the market expanding at approximately 350,000 units per year. This proliferation, in spite of a $1,200 to $2,500 cost per unit and program encryption, indicates that DBS services may have a future in the United States.

4.3.2.1 Status. Currently, the United States has no operational "high-powered" DBS systems. Eleven applications are on file with the FCC for video systems and four are on file for audio systems. In addition, there have been several inquiries into the viability of using DBS for other types of service delivery including data services, news services, and interactive educational programming. Proposed service offerings range from SkyPix's "in-home video store" pay-per-view movie system to the National Rural Telecommunications Cooperatives' Rural TV. Although these applications indicate a high degree of industry interest, it is extremely unlikely that all DBS proposals before the FCC will reach the operational stage.

Figure 4-57 summarizes the status of the "large-dish" direct broadcast market. As previously mentioned, more than 3 million homes receive video programming over these systems. As the figure shows, other than equipment costs and the problems associated with positioning a four-meter antenna, subscription costs for TVRO are competitive with other video alternatives.

FIGURE 4-57
TVRO Large Dish Market Status

		MONTHLY COST	PROGRAMMING CONTENT
Number of Antennas/Receivers	3,000,000		
Turner Broadcasting Company		$ 17.50	(CNN, Headline News, TNT, CBN, Weather Channel, HBO, and Cinemax)
HBO's Flexpak		$ 20.00	(13 basic channels)
Viacom Satellite Systems		$ 20.00	(Nickelodeon, Nick at Nite, MTV, VH-1, ESPN, CBN, The Weather Channel, Lifetime, TNT, A&E, CNBC, Discovery Channel, Showtime, Movie Channel)

Source: Newsbytes 23 April 1992

The current status of the DBS industry is directly impacted by the current situation in the following three areas:

- Enabling technologies
- Market development
- Regulation.

Enabling Technologies

Advances in satellite design, compression techniques, and terminal equipment construction have contributed to the current optimism in the DBS market.

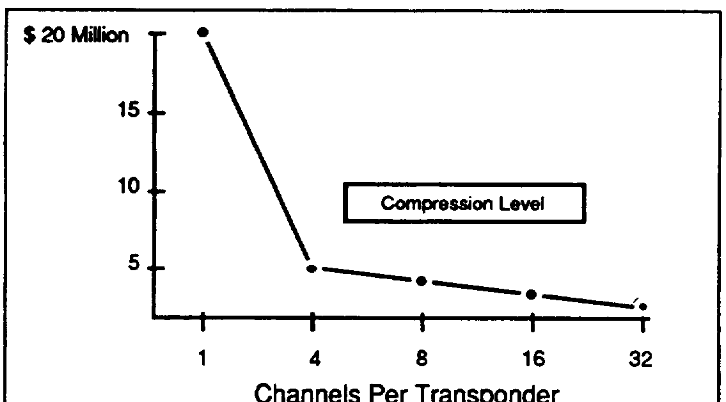
LIGHTSATs, small, capable satellites weighing less than 1000 kilograms, are being developed for DBS use. These satellites, requiring one half the launch vehicle costs of most of today's systems, provide 45-dbW EIRP capabilities, a 7-year design life, and precision navigation to collocate in the orbital arc. Employment of LIGHTSATs can drastically reduce the space segment costs to DBS operators and provide the industry needed flexibility as it adjusts to fluctuations in demand.

Increasing the number of available channels per transponder is a key element in the future success of satellite broadcasting. Currently, the primary method for increasing transponder utilization is through compression techniques. Compression reduces the bandwidth or bits necessary to encode information without reducing the perceived quality of the information itself. In the video and audio arena, data compression exploits the following:

- Statistical properties of the source material
- Psychophysiological properties of observer/listener (RKM Associates October 1991).

Companies such as Thomson Consumer Electronics are developing compression systems that will deliver high-quality signals and provide up to eight video channels per transponder on existing medium-powered Ku-band satellites. The compression algorithm, proposed for Hughes' DirectTV system, the Motion Pictures Experts Group (MPEG) standard, will enable the broadcast of more than 150 channels over 32 transponders. As this technology improves, the per-channel cost of program delivery will continue to fall and the breakeven point for subscriber per-channel costs will be greatly reduced. Figure 4-58 illustrates per-channel costs at varying compression levels (RKM Associates October 1991).

FIGURE 4-58
DBS Cost Per Channel



Channels Per Transponder	Cost Per Channel ($)
1	20 M
4	5 M
8	2.5 M
16	1.25 M
32	625 K

Source: RKM Associates

In the area of DBS-Audio, techniques such as Digital Audio Broadcasting (DAB) will provide highly efficient data reduction of digital audio providing compact disc quality and maximizing transponder utilization. Figure 4-59 summarizes DBS-Audio bandwidth requirements (RKM Associates October 1991).

FIGURE 4-59
DBS Audio Bandwidth

Quality	Basic	Superior	Compact Disk
	5.0 kHz	15.0 kHz	22.0 kHz
FM	67.5 (25)	91.7 (150)	115.9 (200)
PCM	61.4 (66)	68.8 (230)	73.5 (422)
PCM (coded)	56.4 (132)	63.8 (460)	68.5 (844)

Audio DBS. C/N_0 and Bandwidths Required
(Bandwidths in Parenthesis in kHz, C/N_0 in dBHz)

Source: RKM Associates

A critical element in the potential success of DBS systems is the final cost of terminal equipment to the end-user. Due to the lower capital costs of customer premises equipment for competing services, DBS must continue to reduce the costs of its receiving systems. To that end the current state of both video and audio receivers is promising. Thomson Consumer Electronics was recently awarded exclusive rights to develop and sell the first 1 million antenna/receiving units for Hughes' DirectTV DBS system. This system will employ an 18-inch dish at an approximate cost of $700. Other systems under consideration will be able to use receiving dishes of only 12 inches in diameter. There have also been developments in the area of flat antennas with a 25 x 25 cm unit being marketed (The 14th International ... Conference 1992). In the area of DBS-Audio receivers, units are being designed that will take full advantage of digital signal processing. Both mobile and fixed units are being proposed with a variety of antenna options. Technological innovations will continue to reduce production costs and, if the market becomes sufficiently large, per-unit costs will be comparable to other audio receiving units (Meeting with Albert Capriogllio March 1992).

Market Development

Another factor influencing the current status of the DBS industry is the relationship between program providers and program distributors; to have the technological ability to deliver video and audio services is only part of the equation. To develop an attractive programming package, agreements should be established with the full range of national and regional programming networks. Hughes has secured 20 channels of programming similar to that of cable systems for its DirectTV system. SkyPix has noted that it already has agreements with most major

major motion picture companies and many independent production houses to provide movies for its system (Marek August 1991, 2A; Roberts May 1990, 30[5]; Bennet July 1988, 32[5]).

The final area affecting the status of DBS is the regulatory environment. In the United States, the FCC grants all domestic satellite orbital slots and frequencies. Final allocation of orbital assignments and channel allocations are granted after satellite system applicants have signed agreements with satellite manufacturers and launch operators. In 1986 the FCC ruled in favor of allowing U.S. DBS systems to provide other types of services in addition to traditional audio and video during the early years of operation. The FCC has staggered alternative services as follows: the first 5 years of operation have no limits on satellite capacity; during the second 5 years, 50 percent of capacity must be devoted to video and audio; and after 10 years all transmissions must be for video and audio. Until the recent WARC 92, rules for DBS allocation for the Americas were established by the 1983 Regional Administrative Radio Conference (RARC 83). This conference established parameters for bandwidth (24 MHz on 14.58 MHz centers) and determined a 9-degree uniform spacing for satellites serving North America (RKM Associates August 1991).

WARC 92 attempted to establish frequency allocations for Digital Audio Broadcast (DAB) and HDTV. The United States will not use the established DAB frequencies because of interference with aerospace air-to-ground testing. The United States provided nine inputs on the subject of Broadcast Satellite Service (BSS) (Audio). The WARC 92 discussed the allocation of spectrum with the 500 to 3000 MHz range for BSS (Audio). This portion of the spectrum is heavily used and final disposition is still pending. Delegates failed to reach an agreement on a worldwide frequency allocation for HDTV. In Region 2 (the Americas), the 17.3 to 17.8 GHz band was allocated. The WARC maintained most of the provisions relating to DBS established by RARC 83. Consequently, many of the applicants that were waiting for the results of WARC 92 are now proceeding with their plans (RKM Associates October 1991).

In addition to regulations aimed directly at satellite broadcasting, regulation aimed originally at the cable TV industry may impact DBS. Regulation designed to protect local broadcasters by restricting the activities of microwave carriers, forbidding duplication of local programming, and forbidding importation of TV signals without FCC permission will all affect the way DBS systems develop.

4.3.2.2 Plans. The 11 video and 4 audio DBS applications on file with the FCC provide the basis for industry plans. It should be noted that many of the 11 video applications are more than 8 years old and will likely be modified, resubmitted, or canceled as the realities of implementation approach.

In the DBS video arena, Hughes' DirecTV will be the first operational DBS system in the United States with launch scheduled for December 1993. The Hughes system will provide direct broadcast television to the contiguous United States. The initial programming package will contain approximately 20 channels similar to those featured on typical cable television systems. Hughes has secured an agreement with the National Rural Telecommunications Cooperative (NRTC), an organization representing rural telephone and electric cooperatives serving 12 million people in 48 states, to provide the customer interface with its members for DirecTV. The NRTC will pay Hughes up to $250 million for distribution rights. Hughes has also sold transponder capacity to United States Satellite Broadcasting (USSB), which will develop and distribute its own programming package. On the initial DirecTV satellite, USSB will have five transponders and Hughes will retain the remaining 11 with five of those designated for NRTC. A second satellite with 16 transponders all designated for NRTC is also scheduled. When the system is fully operational at 101 degrees West longitude, more than 150 programming services could be offered (Mazer November 1989, 51[3]).

None of the other DBS-video applicants have progressed to the point where concrete plans exist and launch dates have been scheduled. The FCC does not begin to approve frequency allocation until a satellite system has been designed and a launch slot assigned.

In the area of DBS-Audio, much industry attention is being focused on NASA's Direct Broadcast Satellite - Radio Program. This program is designed to assist the U.S. commercial satellite industry in developing concepts and technologies for new applications. The program plans to focus on the following three areas:

- DBS-Radio mobile and fixed reception environment
- Regulatory issues associated with DBS-Radio
- DBS-Radio receiver development.

Collectively these efforts will help provide the technological foundation for commercial DBS-Radio broadcasts and speed the development and production of low-cost receiving units.

4.3.2.3 Deployment. At present the Hughes contract with the European ARIANESPACE consortium for the launch of the DirecTV DBS satellite scheduled for December 1993 is the only firm launch date set for a U.S. DBS system. A second 16-transponder satellite is proposed for the 101-degree West longitude orbital slot, but no launch date is set. The remaining DBS applications currently on file with the FCC have no launches scheduled. Given the age and lack of progress with many of the applications currently on file, it is likely that a reshuffling will take place as the early systems come to market and the acceptance of DBS services can be assessed.

Due to the uncertainty with regard to the primary DBS services, audio and video, no implementation plans exist for additional services. News and data providers will likely lease access capacity from more traditional DBS operators.

4.3.2.4 Costs. There are four categories of costs to the DBS system operator: the capital costs to develop and launch the satellites; the cost of designing and manufacturing the end-user terminal equipment; the cost of acquiring programming; and system operating costs such as satellite operations, advertising, billing, etc. These costs must be covered, and a profit margin allowed for, by the one-time revenue from sale of end-user equipment and the recurring revenue streams from advertising and subscriber fees.

A system operator has several possible strategies available for recovering costs through revenues. At one extreme, he might sell the end-user equipment very inexpensively to build market share, expecting to make up short-term losses from long-term increases in revenue from advertising and subscriber fees over a larger subscriber base. At the other extreme, he might sell (or offer for sale) the end-user equipment well above cost to try to recover other capital costs more quickly.

The construction and launch of a 16-transponder high-powered DBS satellite is estimated to cost about $150 million. Using LIGHTSATs as part of a DBS system may reduce launch costs by $25 million. Costs for leasing a single transponder on a high-powered DBS satellite are estimated at between $10 million and $20 million per year. With current compression technology, this translates into an annual cost per DBS video channel of approximately $1.875 million (Krauss April 1991).

Launch costs for DBS-audio systems are similar to video systems. However, because of lower bandwidth requirements a small number of transponders can supply sufficient capacity for a viable national network.

Equipment costs to the customer will also contribute to the eventual market penetration of both DBS radio and video. As previously mentioned, the large TVRO units currently receiving "normal" satellite broadcasts cost between $1,200 and $2,500. The 18-inch antenna and receiving system being designed by Thomson Consumer Electronics for Hughes' DirecTV will retail at about $700 (U.S. Department of Commerce January 1991).

Receiving units for DBS radio are being examined as part of NASA's DBS-R program. The difficulty in developing a viable receiving unit is that reception is degraded by interruptions in the line of sight from satellite to receiver introduced by buildings, trees, etc. It is predicted that receivers will be developed at costs ranging from $100 to $300 per unit providing fixed, mobile, and portable capabilities (Boeke February 1992).

Acquiring programming is another cost factor that will impact the ultimate cost to the consumer of DBS. A combination of advertising revenues and subscription charges will be used to fund program acquisition.

4.3.2.5 Traffic. Due to the uncertainties associated with the DBS market, traffic estimates have not been provided for this application in this section. Additional information regarding the DBS market and potential traffic is discussed in section 6.0.

4.4 INTEGRATED VIDEO

Video telecommunications service has been technically feasible since 1964. However, demand for this service has only recently started to accelerate, and that demand growth is from a very small base.

The combination of capabilities needed to spur widespread use of video is termed "integrated video." Integrated video would offer wideband service on demand. Another key requirement for integrated video is a set of features that facilitate connections among the broadest possible user community.

Figure 4-60 is a schematic summary of an integrated video application. The five user sites are equipped with a codec, an audio speaker, a microphone, a camera, and a monitor.

The codec encodes and compresses video input for transmission and decodes digital video transmissions for display. The codec performs seven functions:

- Analog/digital conversion between the display and processing formats
- Preprocessing, to reduce the resolution of moving images

- Motion compensation, to divide the screen into blocks that are retransmitted only when they change

- Frequency-domain decomposition procedures to efficiently describe the change in a block

- Quantization, which reduces the number of distinct values needed to represent frame-to-frame changes

- Coding, which conserves bandwidth by assigning short codes to the most common symbols

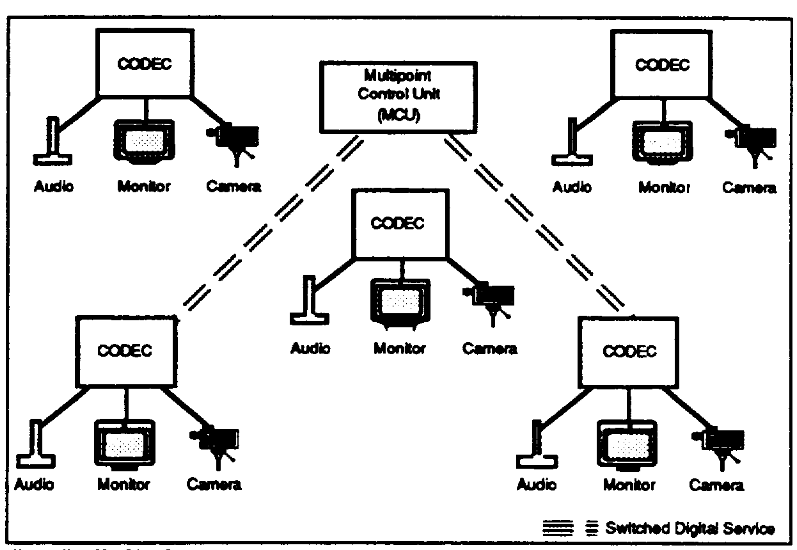
- Interleaving the digitized audio stream with the video stream.

In encoding video, the functions above are performed in the order shown. Decoding video, which requires less intensive processing, performs the functions in reverse order.

The microphone and camera collect inputs from the users for transmission. The audio device varies in complexity, depending on the number of people using a site. The camera ranges from a fixed-focus, wide-angle unit integrated into a multifunction cabinet to a full-feature video camera that can focus on each speaker. The monitor displays video signals from the remote site.

Figure 4-60 illustrates the case of two connected users. Each user has access to a switched digital service, and accesses the service only when it is communicating. This cuts the cost of the many potential interconnections required by a large user community. For any system that must connect more than three users at one time, a Multipoint Control Unit (MCU) is needed. The MCU switches the digital transmissions to keep each speaker's image on all users' monitors. Both digital transmission and MCU functionality can be purchased as services from communications carriers.

FIGURE 4-60
Integrated Video



Source: Booz-Allen & Hamilton

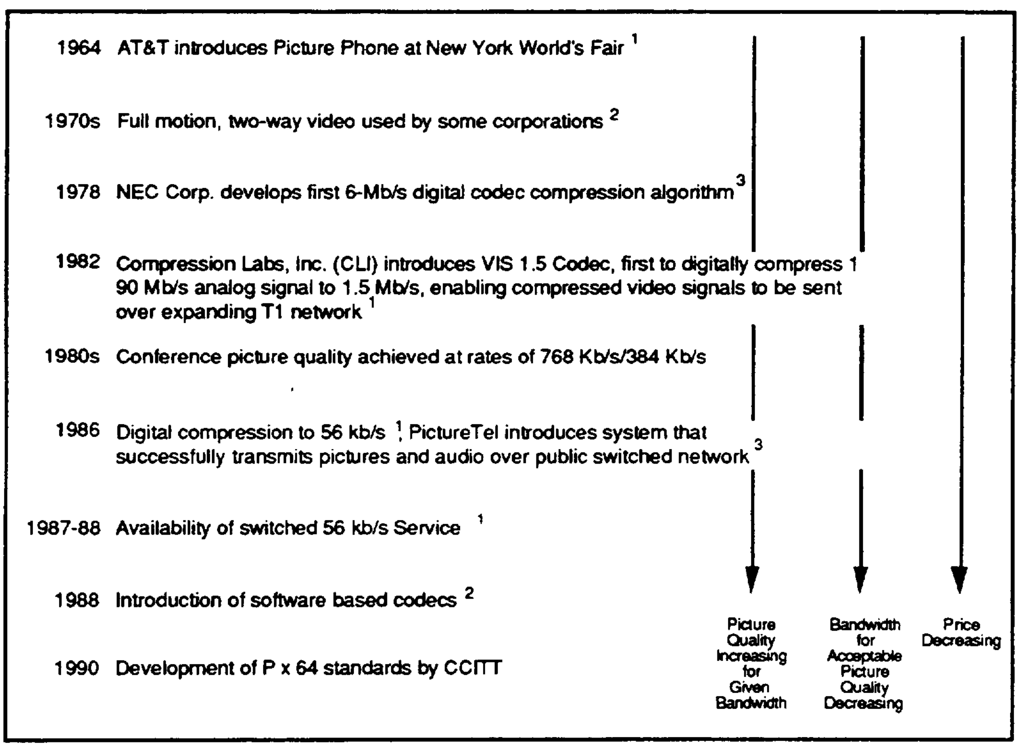
Today several technological and commercial impediments limit the extent of the user community to one of a small number of proprietary, specially designed systems. Before video reaches the potential implied by its current growth rates, the industry must remove these impediments.

4.4.1 Status

The component technologies of video telecommunications have been evolving for more than 25 years without achieving widespread user acceptance. Since 1980, two important trends have accelerated markedly. First, the terms of the trade-off between image quality and bandwidth have improved. Less and less bandwidth is required to provide acceptable image quality, which reduces transmission cost. For a given amount of bandwidth, compression advances deliver increasing image quality. This increases the utility of the service, and expands its potential application. Second, largely due to VLSI, equipment prices have declined. This reduces the investment required to provide a given quality image for an affordable amount of transmission capacity.

Figure 4-61 summarizes video innovations since AT&T's 1964 demonstration of Picture Phone technology. Although the first specialized uses of two-way video in the seventies were followed by accelerating advances in codec technology, video could not provide acceptable performance at a price conducive to widespread acceptance in the eighties.

FIGURE 4-61
Component Technologies of Video Telecommunications



Sources: [1] Walsh 1989

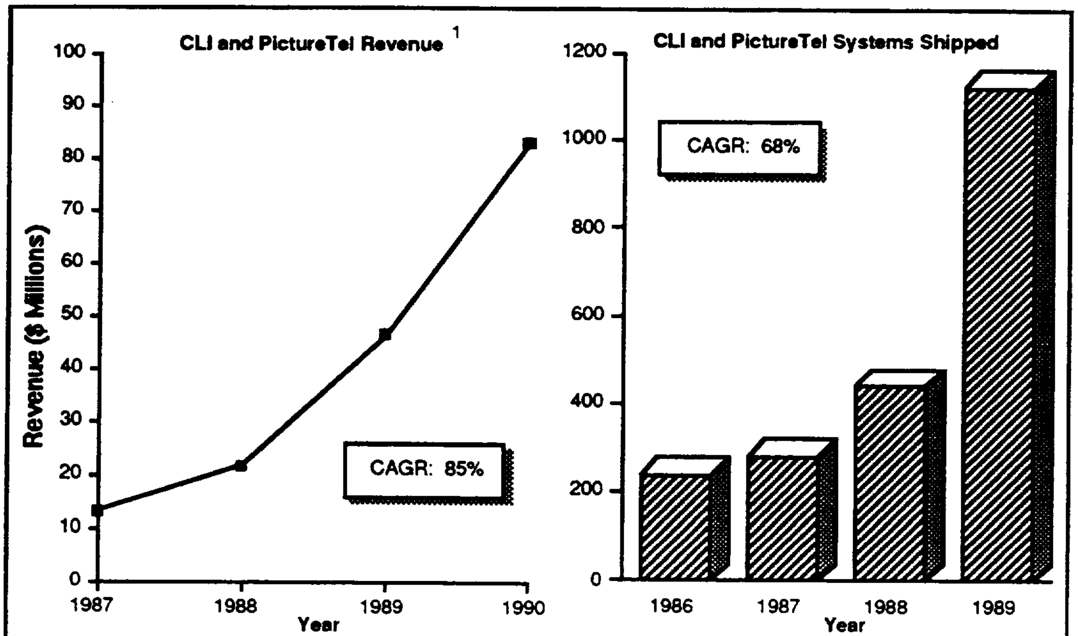
[2] Moeller 1990

[3] Taylor 1991

Leading firms in the codec industry have recently experienced rapid growth from a small base in the videoconferencing segment of their market. As figure 4-62 shows, system shipments grew at a compound annual rate of 68 percent from 1986 to 1989. During the same period, revenues from videoconferencing systems grew even more rapidly, and that growth shows signs of accelerating. These high growth rates have been achieved with systems that serve closed user communities. If interoperability improved, network externalities could fuel even higher growth rates as the value of video service rises with the number of users that adopt the service independently.

The videoconferencing systems industry has undergone a process of consolidation since the 1970's. The industry originally fit a competitive model, with many small firms competing to offer technological solutions. As of 1989, however, 3 of the 30 firms supplying video systems had captured 90 percent of the market. The industry leaders are Compression Labs, Inc., PictureTel, and GPT. Intensified rivalry among a small number of leading suppliers will supplant competition by small firms for customer-specific niches. For both components and integrated systems, industry concentration is high.

FIGURE 4-62
Industry Leaders: Growth from a Small Base

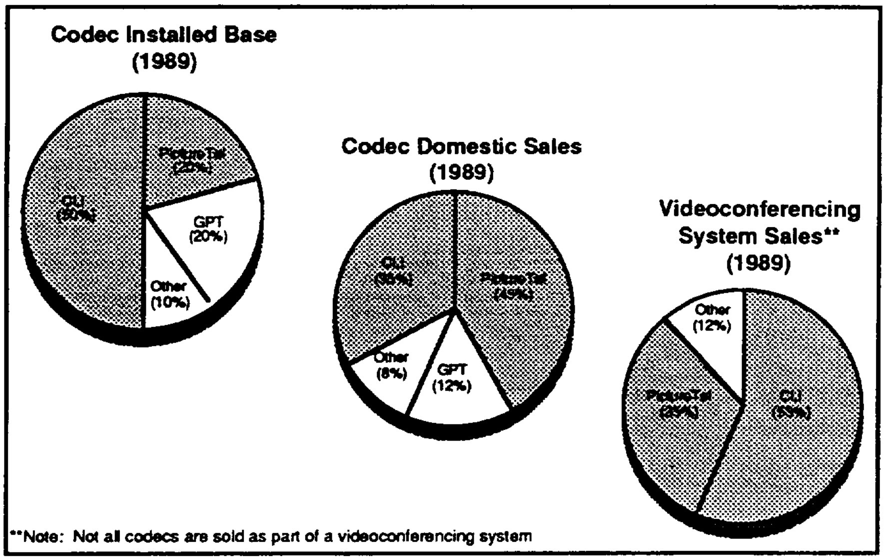


[1] Videoconferencing revenue only

Source: Booz-Allen & Hamilton 1991

Figure 4-63 shows that the videoconferencing system industry is dominated by codec manufacturers. Consequently, efforts have focused on compression technology to improve codec performance. Advances in this area have been impressive: full-motion video required 6 Mb/s in 1978, but was possible over fractional T1 10 years later.

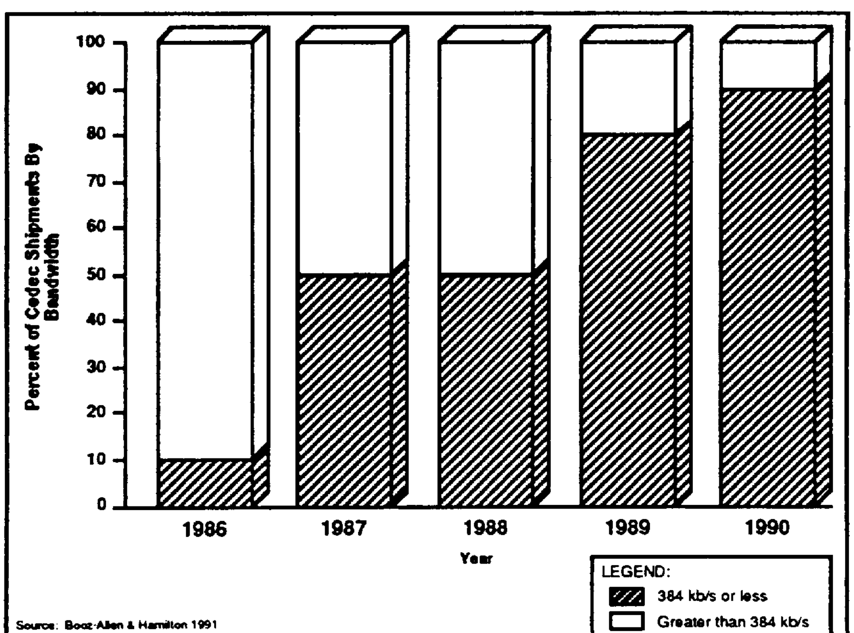
FIGURE 4-63
Video Codec Supply



Source: Booz-Allen & Hamilton 1991

Figure 4-64 shows the benefits of codec advances in users terms. Since 1986, more and more codecs have allowed systems to make use of cheaper sub-T1 links. Codec advances have cut usage-sensitive costs, which are increasingly important to user acceptance in a switched service environment. According to Robert M. Fredericks of Bellcore, 384 kb/s has become the industry standard for videoconferencing.

FIGURE 4-64
Codec Advances Have Cut Usage-Sensitive Costs By Exploiting Sub-T1 Links



Compression improvements left gaps with important effects on user acceptance, however. Codecs were not effectively integrated with transmission networks and auxiliary equipment. Audio filtering algorithms had mixed success in countering noise and echo. Standards took a long time to evolve. And transmission pricing was inappropriately high for video use. Each of these factors will be discussed below.

Integration

As codecs improved, their integration into video systems lagged. Video conferences required intricate setup procedures that could only be performed by trained technicians. Setup complexity complicated the process of scheduling a videoconference, and tended to inhibit the use of installed systems. AT&T performed the most comprehensive assessment of human factors when it launched the video phone as a consumer product. The result of AT&T's ergonomic and consumer preference studies was a terminal with screen prompts and camera view indicators to assist users with novel video requirements. The video phone receives ordinary telephone calls and video calls, which keeps users connected to the public voice network.

Audio

Audio encoding and decoding were sensitive to extraneous noise. In conferencing applications, this caused video switches to lock onto sources of extraneous noise, such as shuffled papers, falling objects, etc. The problem was most acute in the largest and potentially most cost-effective conferences. Audio transmission also remains very sensitive to room layout. This makes room preparation a significant initial cost of high-quality conferencing systems.

Standards

A lack of compression standards limited systems to closed user communities with equipment of the same make. Currently evolving standards with the potential to resolve this problem will be discussed in section 4.4.3.

Transmission pricing

AT&T, the leading supplier of switched digital service, perceived this service mainly as a backup to dedicated lines. Accordingly, AT&T priced switched digital at a premium, mitigating the advantages of dial-up availability for video. At relatively low levels of use, video conferencing systems had to incorporate dedicated lines for cost-effectiveness. Absence of affordable switched service increased the fixed costs of a video system, and inhibited the expansion of networks to serve light or occasional users.

4.4.2 Plans

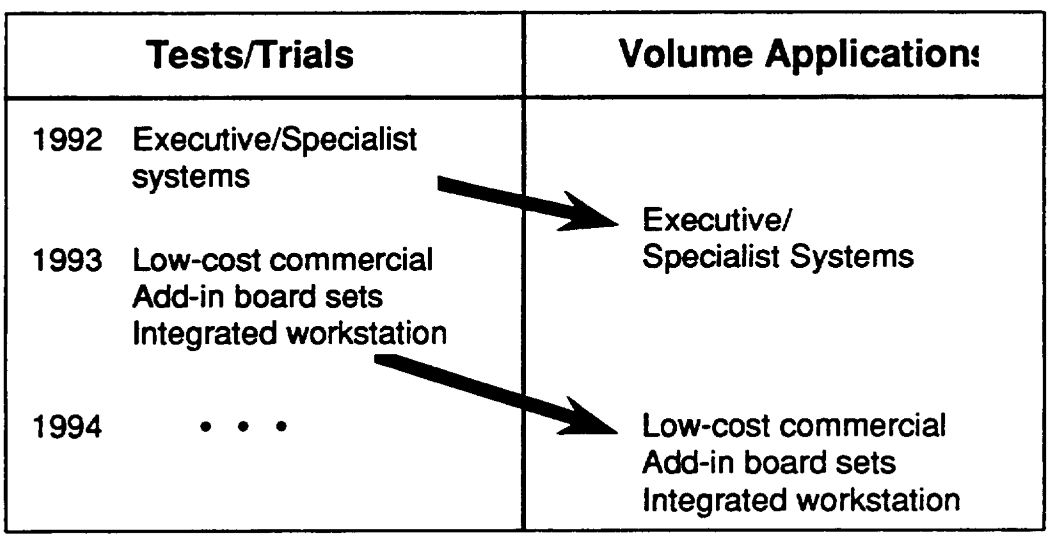
Video suppliers are working toward a goal of commercially-ubiquitous systems of desktop size. Dick Moeller, the CEO of Video Telecom, has articulated a concept of following new system trials with volume production in the next year. Figure 4-65 illustrates the resulting progression of improvements. Special purpose systems fielded in 1992 would be moved to volume production in 1993. In 1993, new products conducive to general use would be tested. The 1993 innovations would include equipment to integrate video into desktop computers and low-cost, general purpose equipment. New tests of more advanced innovations would follow in

1994 for large scale commercialization in the next year. Product cycles this short could result in rapid improvements in price and performance.

Compression innovations can be generated by the needs of four diverse markets: broadcasting, business TV, videoconferencing, and videophone. The purposes and engineering requirements of each market are different, but advances in systems for one market benefit other types of codecs. For this reason John Boyd, the Director of Technology and Market planning for CLI, states that it is advantageous for his firm to span all four markets.

Nonetheless, industry activity centers on desktop or personal video over POTS lines. Figure 4-66 summarizes some recently announced products. Suppliers may cooperate or compete at different times and for different markets. CLI supplies the codec for AT&T's product, along with other codecs for its own systems. Prices cluster in a small range above $1,000. Prices at this level do not seem to be constrained by production costs: John Slevin, marketing director of AT&T consumer products, states that the $1500 price of the VideoPhone is based on consumers' willingness to pay as expressed in market testing. Suppliers' market studies indicate that buyer price preferences might not be linked to voice telephone costs because video telephony is perceived as a completely different experience.

FIGURE 4-65
1-Year Generations Evolving Toward Desktop Size and Commercial Ubiquity



Source: Dick Moeller, VideoTelecom CEO (COMNET '92)

FIGURE 4-66
Desktop or Personal Video Over POTS Lines

	SCREEN	FRAMES/ SECOND	MODEM	PRICE
CLI	128 x 112	10	14.4 Kb/s	$1800 minimum*
Comtech Labs	640 x 480	12 – 15	4.8/19.2 Kb/s	$1200 – 1500
AT&T	128 x 112	2 – 10	19.2 Kb/s	$1500

*see Section 4.4.4
Source: Manufactueres' data

Designers for equipment suppliers feel that the compression level of codecs for POTS has reached the limit imposed by low POTS transmission rates. More bandwidth, not codec advances, will further drive quality improvements through 2000. Most quality improvements will result from the greater bandwidth made available by ISDN services because any codec algorithm operating near its minimum transmission rate improves image quality greatly with a small amount of incremental bandwidth.

4.4.3 Deployment

The deployment of integrated video depends on supply and demand factors. Supply will be determined by technological factors that affect the cost and performance of components. Demand will depend on the services integrated video can provide.

To attract the traffic targeted by suppliers' plans, video technology must attain two technical milestones: industry standards must converge and gain full acceptance, and user equipment must become more integrated.

Standards

In December 1990, the CCITT recommended the Narrowband Visual Telephone Systems and Terminal Equipment Standard, H.320. This standard included H.261, a standard for Compressed Digital Video algorithms. This standard uses the Discrete Cosine Transform (DCT) algorithm for frequency domain decomposition. Use of DCT makes it possible for suppliers to treat video transmissions as a standard sequence of data values. With H.261, suppliers can process bandwidth up to T1 in increments of 64 kb/s, and display it in two formats. The two formats are Common Interface Format (288 lines by 360 pixels at 30 frames per second) and Quarter CIF (144 lines by 180 pixels at 30 frames per second). Standards for high-resolution graphics, encryption, and multipoint video are pending.

All suppliers now conform to H.261. However, vendors continue to compete with proprietary algorithms that offer higher quality links between codecs of the same make. Many codecs will first attempt to use their proprietary algorithm, and fall back to H.261 only if the first attempt fails. This strategy gives user groups an incentive to converge on a single vendor's products. But it impairs transparency across systems, which has been one of the barriers to video use.

Standards issues affect transmission and encoding. One problem is that the subtle differences among carriers' implementations of transmission standards result in distinct versions of ISDN and switched 56 service. The differences can impair video quality when multiple carriers help provision a video link.

Now that H.261 has defined video as a specific form of data, existing data services can be more easily applied to video needs. ISDN gains a role in providing bandwidth on demand, a key component of integrated video. However, existing ISDN implementations have a weakness that reduces the utility of video telephony. Robert Fredericks of Bellcore summarizes the weakness as a "gulf" between voice and data bearer channels. Differences in call setup, signal processing, and conferencing features make it difficult to complete a call without detailed information on the called party. Ideally, standard phone users should be able to receive video calls on a voice-only basis. Video calls using two ISDN B-channels should be transferable. The Multi-Use Bearer (MUB) service is being defined to provide these features for incorporation into Bellcore requirements and guidelines.

Integration

The key enabling technology for integrated video equipment is Very Large Scale Integration (VLSI). According to the Gartner Group, VLSI is needed to reduce the cost of "glue" electronics that integrate the functions of peripheral equipment. With VLSI, chips for still quality images can attain refresh rates of 30 frames per second, at a unit cost of $200 in preproduction quantities.

Based on applications cited by major suppliers and service providers, current demand for video telephony is generated by a broad range of uses. Industry-specific tasks give rise to much demand, particularly for store-and-forward capabilities. But video can also meet general needs applicable to residential or business use. A partial list of applications includes the following:

- Telecommunications for the hearing-impaired
- Enhanced 900 services
- Remote inspection of objects
- Remote examination of people
- Videoconferencing
- Design
- Sales
- Training
- Recruitment/selection
- Surveillance.

Figure 4-67 illustrates video applications reported or considered by CLI and PictureTel customers. Videoconferencing is most prevalent among three reported applications. The manufacturing industry seems to have applied video to the most diverse set of functions. However, figure 4-67 indicates that video is a long way from the commercial ubiquity envisioned by its providers.

FIGURE 4-67
Reported Applications for Video Growth

	Federal Government	Retail Trade	Transportation	Banking/Financial	Insurance	Utilities	Manufacturing	Business Services	State/Local Government	Wholesale Trade	Education	Health Care	AG/Mining Construction
Hearing-Impaired Telecom											O		
Remote Inspection		●				O	●						
Remote Examination						O		●	●			●	
Conferencing	●	●	●	●	●	O	●	●					●
Design							●						●
Sales				●			●			O			
Training		●		●	●		●				O		●
Recruitment/Selection					●								
Surveillance			●			O							

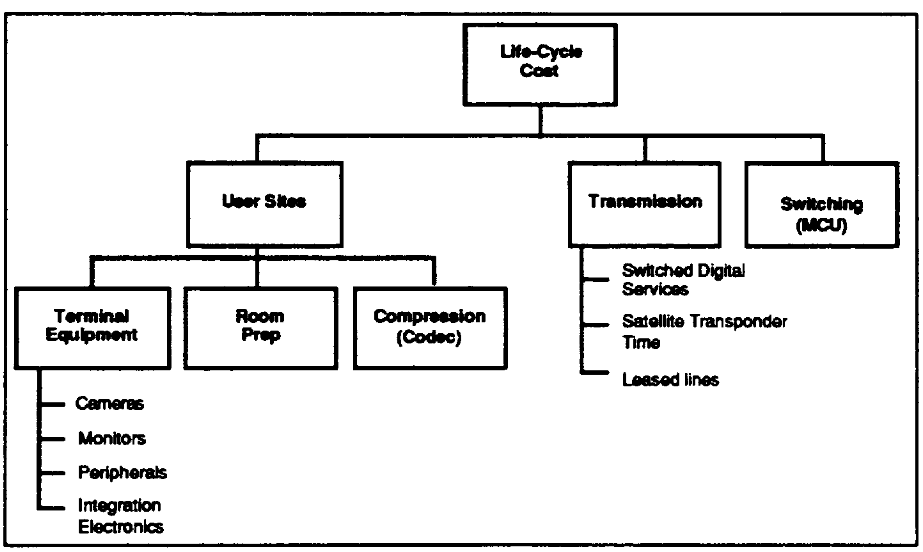
LEGEND
● Reported Applications O Potential Applications

Source: Booz-Allen Analysis

4.4.4 Costs

Figure 4-68 shows the cost of an integrated video system divided according to the network elements involved. Life-cycle cost can be associated with user sites, transmission, or switching.

FIGURE 4-68
Integrated Video Costs Organized by the Function of Network Elements



Source: Booz-Allen & Hamilton

User site cost can be subdivided into terminal equipment, room preparation, and compression. Terminal equipment has certain predictable cost elements: a camera, a monitor, and peripherals, such as audio speakers, microphones, and integration electronics. Room preparation costs may vary widely depending on the application and the terminal equipment. Single-user systems or sophisticated rollabout systems may require less room preparation. Site costs vary with the number of system users.

Video telephony terminals fall into one of two categories: those similar to telephones, and those based on desktop computers. The distinctive cost components of each type of terminal are the same: a codec chip, a camera, and a monitor.

Codec chip price and performance trade-offs should improve rapidly in the near future because the market for video compression is now large enough to attract the attention of major chip manufacturers with access to advanced VLSI technologies and recent manufacturing innovations (Walsh 15 May 1992). Nevertheless, codec chip suppliers predict that codec chips will not achieve the $200 level before 2000 because the actual price of the simpler 80486 chip is a minimum of $150 even though it has a mature design. The newer and more complex video chips will remain more costly for some time. Camera costs vary, because low volumes for this application have not generated commodity costs for standard designs. Monitors for video telephones are specially designed whereas desktop computer video terminals simply use the computer monitor.

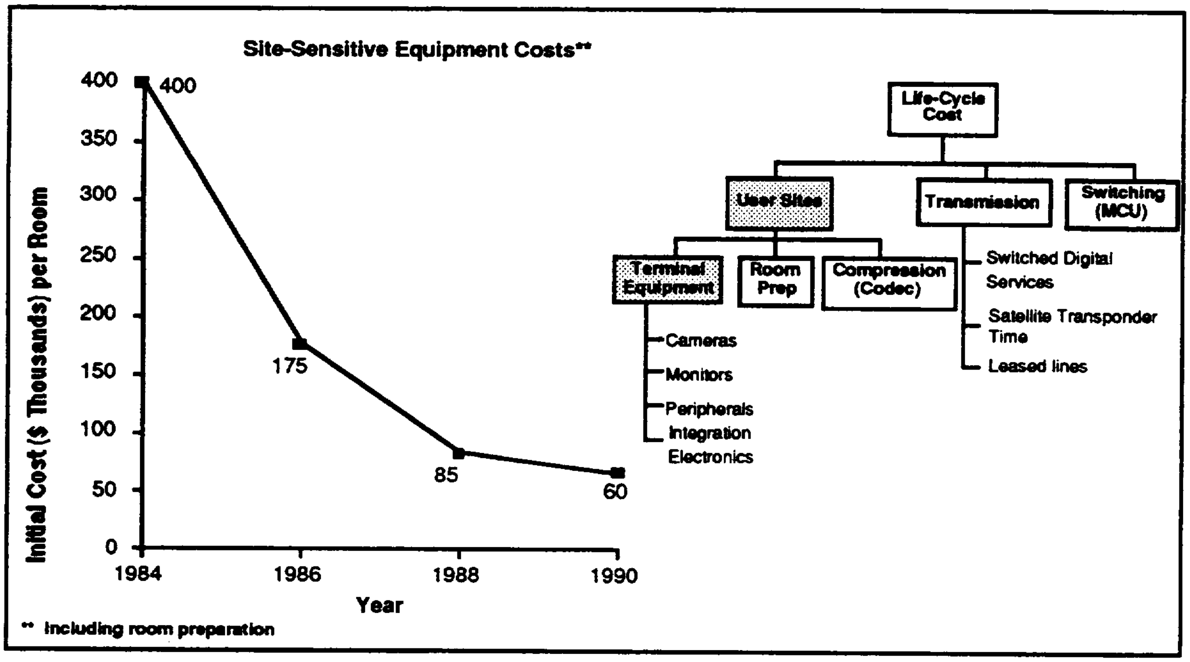
Desktop computers with video capability cost somewhat more than telephone-type terminals, but recently announced products are still less than $2,000. Installation cost of a video-capable computer is more complex than for a videotelephone because incremental cost depends on whether or not a new user is enhancing an existing computer system, and on the capability of the existing system. Using the example of CLI's Cameo Personal Video System, a complete videocapable Macintosh workstation would cost $8,000. Many new users would be upgrading already purchased computers, however, and this would cut costs. At a minimum, Macintosh users would need to purchase a $1,595 external codec and a $200 camera. Many existing Macintosh users will also need to upgrade their computers with ISDN and video display cards.

Transmission costs include only one, or a combination of services. Switched digital services can be combined with leased lines or transponder capacity, depending on calling patterns. Transmission costs vary with the number of users, but can also be significantly affected by network topology. Use of switched services can also make costs vary with usage.

Switching or bridging costs are associated more with conferencing than with two-way telephony. For switching, the cost of an MCU can be shared among several users.

As figure 4-69 shows, site costs for videoconferencing equipment have declined about 38 percent per year since 1984. This is due to advances in VLSI technology and experience effects from increasing production volumes.

FIGURE 4-69
Aggregate Site-Sensitive Costs Have Declined About 38 Percent Per Year Since 1984

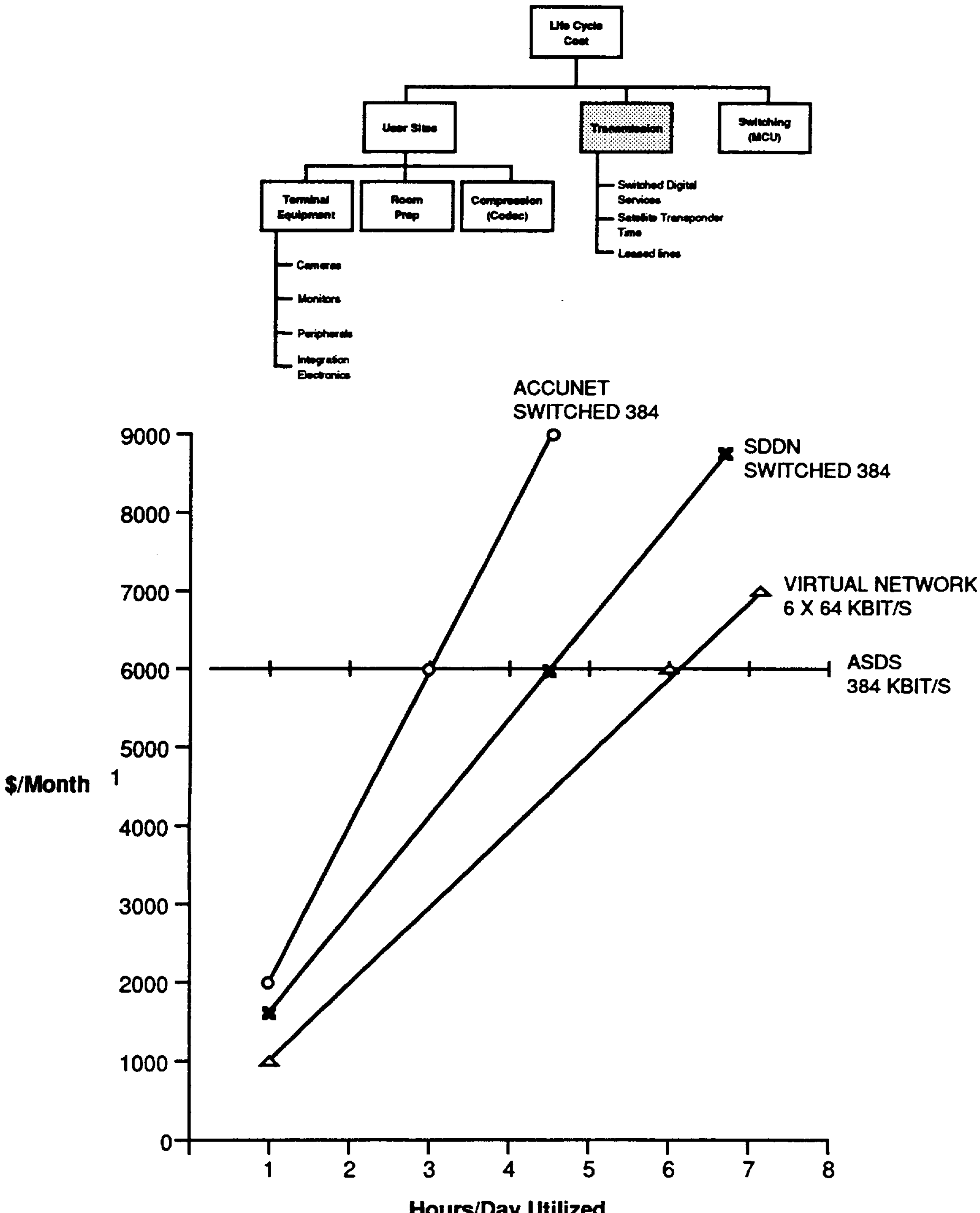


Source: Booz-Allen & Hamilton 1991

Figure 4-70 highlights an important development affecting transmission costs. Dedicated circuits are no longer the sole cost-effective choice for video transmission. Leased lines are now supplemented with several types of switched services, offering different combinations of network control and special features. This development means that new users of video communications do not face the cost hurdle of fixed transmission costs. Limited usage during an initial adoption period will reduce costs. Cost-effectiveness becomes less dependent on maintaining a threshold level of usage, so that video communications is more readily adapted to users' needs.

Figure 4-71 illustrates that transmission costs have fallen as transmission services adapt to users' needs. Hourly transmission costs for Sprint's Meeting Channel declined by more than 90 percent between 1984 and 1990.

FIGURE 4-70
Switched Digital Services Cost

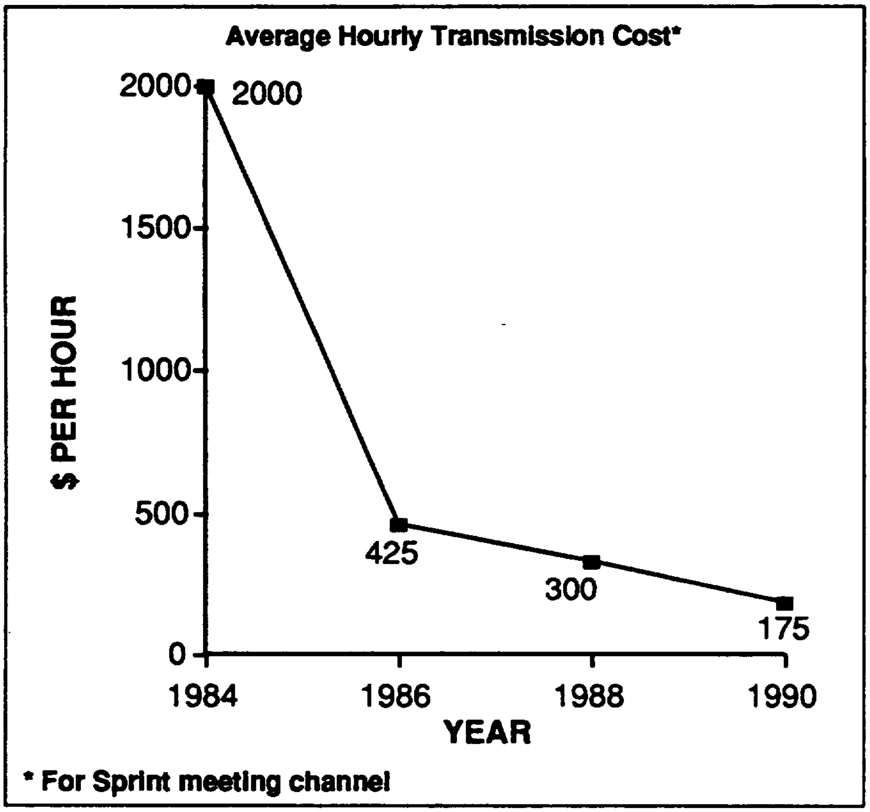


[1]AT&T Prices Effective 11/1/91

Source: *Data Communications*, AT&T

SDDN: SOFTWARE DEFINED DIGITAL NETWORK
ASDS: ACCUNET SPECTRUM OF DIGITAL SERVICES

FIGURE 4-71
High-Speed (Up to T1) Services



Source: Sprint

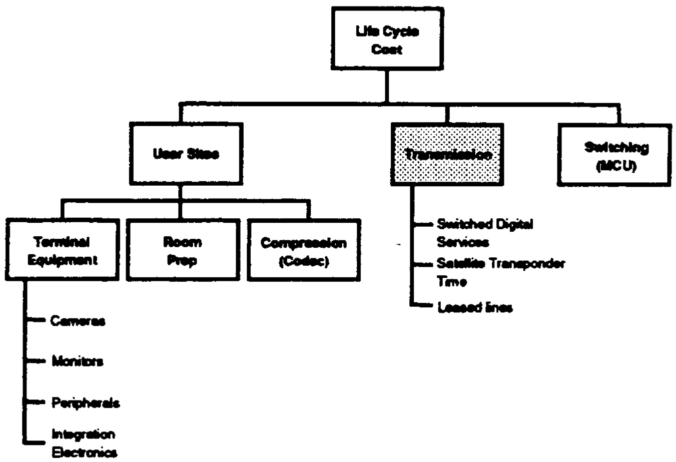
As codecs advance, they are able to provide better quality service at lower transmission speeds. For users willing to accept lower transmission quality in return for cost reductions, 56 kb/s transmission costs permit further control over costs. Figure 4-72 illustrates a notional network spanning the United States. As with higher bandwidths, monthly transmission cost depends on whether usage patterns are matched to the type of service purchased.

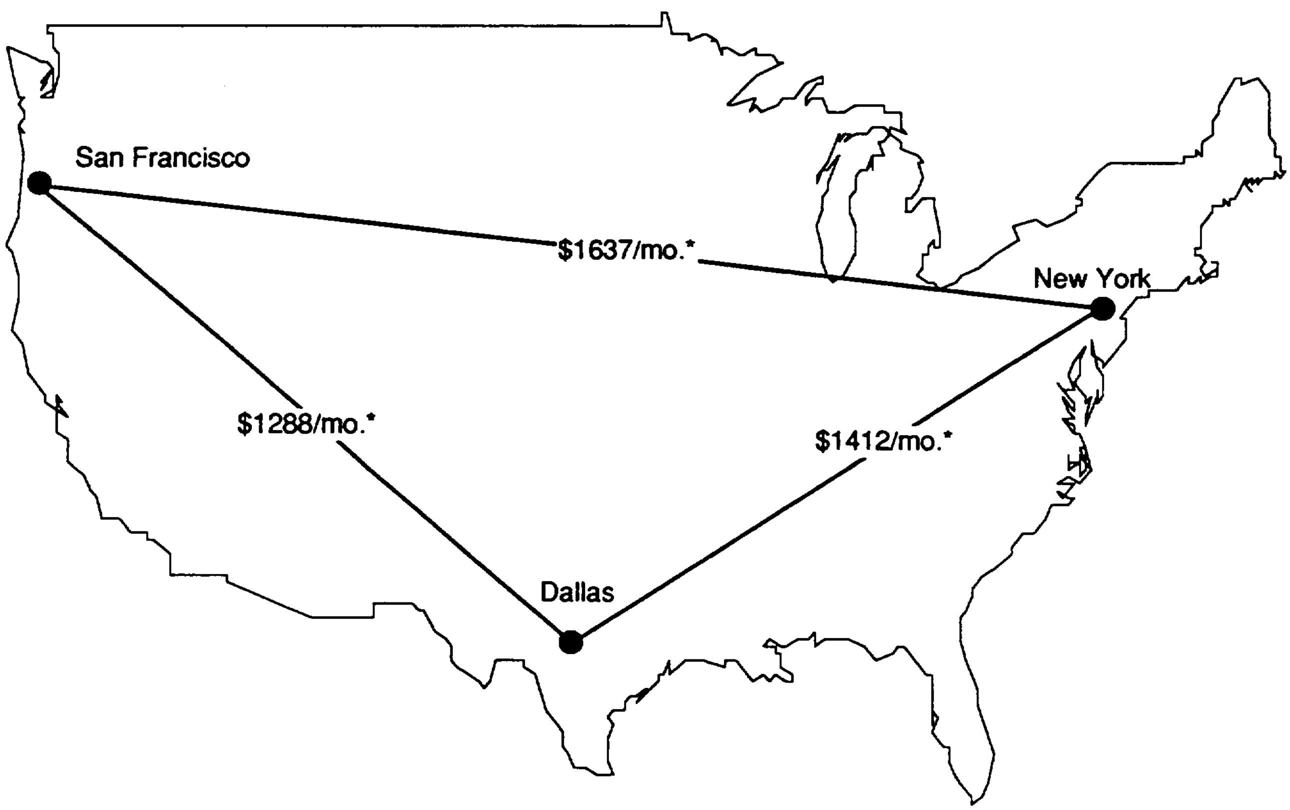
Multipoint Switching Units are relatively new products. Although prices have not been driven down to commodity levels, rapid improvement in features and capabilities leads to a wide choice of price alternatives. Pricing is feature-based; MCU features provide additional flexibility in adapting to specialized user needs or simplifying call initiation, for a price. Features may include the following:

- Auto answer
- Auto dial
- Auto setup
- Bandwidth flexibility
- Simultaneous conferences
- Encryption.

The first three features reduce the setup complexity discussed above. The fourth feature allows users to balance cost and image quality for individual conferences, rather than once for all in the

FIGURE 4-72
56 kb/s Cost





*1992 Rates; not including initial cost ~ $2000 system design process. Bandwidth flexibility encompasses 56 kb/s, fractional T1, or T2. The fifth feature makes it easier to use the MCU at capacity by serving separate groups of conferees with the same switching unit. Some products can accommodate separate conferences using different transmission rates or codec algorithms. Encryption addresses security concerns that may have inhibited video growth in the past.

Investment costs for video switching range from $10,000 to $25,000 per port, but cost is shared among all the ports using the equipment. Consequently, network configurations that use MCUs at capacity are important in controlling cost. MCU switching capacities are normally augmented by cascading multiple units. The type of modularity now afforded by packet switches is unavailable with MCUs. This means that video networks accommodate growth in usage intensity or the user community with more difficulty than data networks.

Figure 4-73 summarizes the cost elements discussed above in terms of the factors that influence each. As shown in figure 4-73, the user population directly affects user-site costs. Switching costs also depend on the number of separate user sites, but cost may vary as a step function of user community size because MCUs provide capacity in discrete quantities. The geographic dispersion of users primarily affects transmission costs if terrestrial transmission is used. The topology of the network affects the relative allocation of resources among switching and transmission. Usage directly affects only transmission costs when a dedicated network is used. Conferencing services like Sprint's meeting channel distribute all costs on a usage basis.

FIGURE 4-73
System Cost for Users or Services Providers

Cost Driver / Affected Costs	User Site Costs	Transmission Costs	Switching Costs
User Population	●		●
Distance Between Users		●	
Network Topology		●	●
Usage		●	

Source: Booz·Allen Analysis

4.4.5 Traffic

Integrated video applications will account for an appreciable fraction of the traffic forecast in section 2.5.4. The primary factor affecting the volume of integrated video traffic is integration of voice and data services. ISDN will be a critical factor promoting the growth of integrated video. Robert M. Fredericks of Bellcore projects that full feature videotelephony

However, video telephony will concentrate for the near term on low bandwidths, to capture residential and business markets that rely on POTS rather than ISDN.

Integrated video will dominate intermediate-bandwidth service, and especially the limited-full motion video market. Traffic projections for integrated video through the year 2011 are provided in figure 4-74.

FIGURE 4-74
Integrated Video Traffic Projections

DSOs	DSO Units	Busy Hour Traffic Projections 1991	1996	2001	2006	2011	Traffic Allocation Factor*
Voice							
MTS (Business)	DSOs (10^6)	-	-	-	-	-	-
MTS (Residential)	DSOs (10^6)	-	-	-	-	-	-
Private Lines	DSOs (10^6)	-	-	-	-	-	-
800	DSOs (10^6)	-	-	-	-	-	-
900	DSOs (10^6)	-	-	-	-	-	-
Private Networks	DSOs (10^6)	-	-	-	-	-	-
Data							
Facsimile	DSOs (10^3)	-	-	-	-	-	-
E-Mail	DSOs (10^3)	-	-	-	-	-	-
Terminal Operations	DSOs (10^3)	-	-	-	-	-	-
On-Line Info. Services	DSOs	-	-	-	-	-	-
EFT	DSOs (10^3)	-	-	-	-	-	-
EDI	DSOs (10^3)	-	-	-	-	-	-
Video							
Network Broadcast	DSOs (10^3)	-	-	-	-	-	-
Cable TV	DSOs (10^3)	-	-	-	-	-	-
Educational TV	DSOs (10^3)	46.0	5.1	13.0	14.0	14.0	1 – 0.5
Business TV	DSOs (10^3)	0	36	53	95	115	0 – .6
Viewer Choice TV	DSOs (10^3)	-	-	-	-	-	-

Source: Booz-Allen Analysis

* Traffic allocation factors are the fractions of total traffic that represent potential integrated video traffic

4.5 MOBILE SATELLITE SYSTEMS

Mobile satellite systems are designed to deliver a range of communication services to a wide variety of terminal types. Mobile satellite terminal platforms include land vehicles, aircraft, marine vessels, and remote data collection and control sites. Portable terminals used for these services are currently "briefcase" size, but may be reduced to "handheld" size for future systems. Basic mobile services supported by these systems include voice, data, paging, and position determination.

The space segment for mobile satellite systems is based on two concepts that are not necessarily mutually exclusive: large satellites in geosychonous orbit or small low- or medium-earth orbiting satellites. Large geostationary satellites use large antennas and in the future may operate at higher carrier frequencies. The combination of large antennas and high carrier frequencies can be used to create spot beams that result in major increases in system capacity due to frequency reuse. Small satellites placed in low-earth orbit offer the advantages of greatly reduced transmission path loss and much smaller propagation delays over using geostationary satellites. Although smaller satellites are less expensive to build and launch, many more satellites are required to provide the same coverage as one geostationary satellite.

The types of mobile satellite communication channels available to the user are divided into three categories: store-and-forward packet data channels, interactive packet data channels, and circuit-switched channels. Store-and-forward packet data channels, which are the easiest to implement, transmit small amounts of user data with delivery times of several minutes. This type of channel is typically used for cargo tracking services, paging, and some emergency distress signaling. Interactive packet data channels are used for services when the several minute transmission delay is unacceptable. These services are typically interactive messaging services used for inquiry-based data retrieval, and many emergency and distress applications. Circuit-switched channels are used for applications requiring real-time voice communications or for transmitting large amounts of data, such as facsimile or file transfers. Voice services provided by mobile satellite systems are similar to those provided by terrestrial-based cellular systems, but to a larger geographical area (Lodge, November 1991).

As illustrated in figure 4-75, mobile satellite systems may include a gateway earth station that provides an interface with the public switched telephone network and communicates with mobile terminals via satellite. Systems can also be configured to provide services among a closed user group, such as a government agency or company, with satellite communications being provided between mobile terminals and a base station. Systems typically also include a network operations and control center that provides network monitoring, configuration and control functions.

Although the FCC assigns specific frequencies and names for voice, data, and position determination mobile services, for the purposes of this report we have considered these services as part of mobile satellite services (MSS). We believe this approach is valid because most of the systems designed to support a specific service could also support many of the other mobile services with minimal additional system investment. For example, companies providing RDSS also can provide data messaging capabilities, and companies providing voice services could easily expand their services to include positioning services by transmitting terrestrial-based positioning data via satellite (Gartner Group Consulting, September 1991).

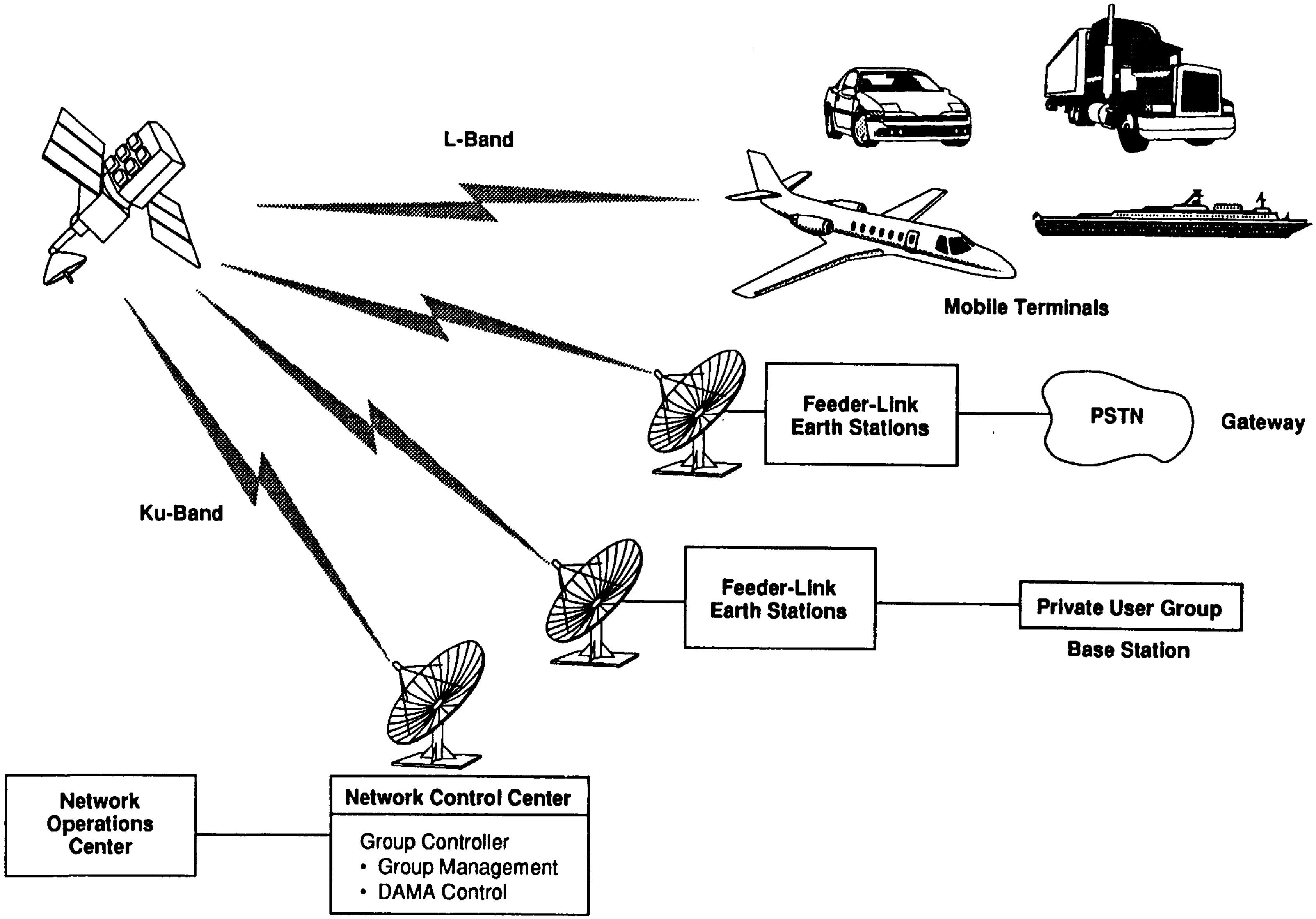
4.5.1 Status

Service Providers and Equipment Manufacturers

A variety of service providers exist and are emerging in response to growing demand for mobile satellite services to support land, aeronautical, and sea-based applications. Inmarsat and Qualcomm are currently providing service in the United States, demonstrating the economic viability of these systems. However, most potential commercial mobile satellite service providers' systems are still in the planning stages with filings before the FCC. Service providers have expressed a wide variety of spectrum requirements for mobile satellite systems ranging from 1 MHz to 220 MHz of bandwidth in L-, S-, C-, Ku-, and Ka-bands. Additionally, a variety of concepts have been proposed for these systems ranging from the use of new or existing geostationary satellites to systems based on low- or medium-altitude satellites.

Inmarsat, the oldest mobile satellite service provider, began offering service in 1982 using three Marisat satellites leased from Comsat and subsequently using two Marecs satellites from the European Space Agency and four maritime communication packages on Intelsat satellites (Wood, November 1991). As a result of continued steady growth in demand for services, Inmarsat has ordered a second generation of satellites, the first of which went into

FIGURE 4-75
MSS System Overview



service in 1990. Contracts for four third-generation Inmarsat-III satellites were awarded in 1991, with delivery of the first satellite scheduled for July 1994. Inmarsat's third generation satellites will be equipped with spot beams to permit frequency reuse, an L-band-to-L-band link for direct mobile-to-mobile communications, and a navigation payload that will enable development of a civilian version of GPS and Glosnass navigation systems.

Initially chartered to provide emergency and distress communications capabilities for maritime applications, Inmarsat today provides worldwide communications service for land, air, and sea applications. The organization's maritime service is based on the Inmarsat-A terminal, which supports voice and data applications using a 56 or 64 kb/s channel. Smaller and less expensive, the Inmarsat-C terminal can also be used for maritime applications supporting low data rate transmission at 600 b/s. Approximately 12,000 Inmarsat-A terminals and 1,200 Inmarsat-C terminals have been installed on vessels and are in operation today (Wood, November 1991). Inmarsat's aeronautical services allow direct-dial telephone access from an aircraft to more than 180 countries, a service previously available to only parts of North America. An increasing number of Inmarsat-A and Inmarsat-C terminals are being used for land-based communications. To date, more than 2,000 Inmarsat-A and 1,000 Inmarsat-C terminals are in use for land based applications.

Qualcomm, Inc. is the only provider of MSS in the United States that uses Ku-band frequencies for transmission links between mobile terminals and the satellite, and therefore does not have to compete with other service providers for limited L-band spectrum. Based in San Diego, California, Qualcomm began operation in 1985 and has invested more than $50 million in its MSS technology. It is a privately-funded company that designs, develops, and manufactures advanced communications systems for consumer, government, and industry applications.

Qualcomm currently operates OmniTracs, a satellite-based mobile communications system that provides two-way, real-time messaging and positioning data between fleets and their operation center. The company originally bought the rights to the OmniTracs product in 1988 from Omninet, a Los Angeles-based start-up company. Qualcomm's system uses existing Ku-band satellites, which resulted in greatly reduced start-up costs. Qualcomm's business base has continued to grow with recent contracts being signed with major customers that formally were served by Geostar.

The American Mobile Satellite Corporation (AMSC) was formed in June 1989 as a consortium of eight companies: Hughes Communications Mobile Satellite, MTEL Satellite Service Corporation, McCaw Space Technologies, Mobile Satellite Corporation, North American Mobile Satellite, Satellite Mobile Telephone Company, Skylink Corporation, and Transit Communications. In late 1991, the FCC refined its license to AMSC by allowing three more firms to join the consortium: Global Land Mobile Satellite, Globesat Express, and Mobile Satellite Service. AMSC's portion of the L-band was also set at 1545 to 1559 and 1646.5 to 1660.5 MHz.

4.5.2 Plans

Service Providers and Equipment Manufacturers

AMSC plans to launch three geosynchronous satellites at a cost of $444 million. AMSC and Telesat Mobile Inc. (TMI) of Canada are constructing identical satellite systems to provide mutual backup and seamless services for all of North America. Hughes Space and Communications Group (bus) and SPAR Aerospace (payload) are under contract to build the satellites. AMSC and TMI will initially share the TMI satellite at 106°W when it is launched in early 1994. Later that year, AMSC will transition to its own satellite at 101°W. AMSC's other satellites will go into slots at 139°W and 62°W.

Each AMSC satellite will handle 2000 5-kHz channels, providing sufficient system capacity to support 600,000 subscribers. Feeder frequencies are 13/14 GHz uplink, 11/12 GHz downlink. The network control system are in two separate facilities: the Satellite Operations Center for satellite control, and a Network Operations Center for network control and channel access. The network will feature priority and preemptive access for aeronautical safety services. Gateway stations will connect from 1 to 100 channels to the PSN, while fixed base stations will interconnect one to a few channels to private networks. AMSC envisions users to include:

- Trucking companies
- Police, fire, and rescue
- Railroads
- Remote mining, lumbering, and industry
- Nonurban businesses
- Private automobiles
- Commercial aircraft
- Private aircraft
- Fishing fleets
- Paging.

Mobile units for the AMSC system are projected to cost $3000, with monthly service charges in the $80 range. Users will be charged about 82 cents per minute for services including two-way voice communications, mobile facsimile, PSN access, private networks and vehicle tracking. Mobile-to-satellite links will be in the 1613 to 1626.5 MHz portion of the L-band. NASA will provide launch services on Atlas or Titan vehicles in exchange for 2 years of service, during which time the Government will conduct experiments to determine if AMSC can meet Government requirements. At the end of 2 years, any government users desiring to continue to use the system would become commercial customers.

In early 1992 the FCC granted Volunteers in Technical Assistance (VITA) "pioneers preference" for their LEO satellite system, denying preference to Orbital Communications Corp. (Orbcomm) and STARSYS, Inc. (Argos). Orbcomm and Argos were deemed to not offer any substantial innovation beyond the existing communications technology, while VITA was deemed to be first to propose "to provide communications to unserved persons throughout the world with inexpensive LEO satellites."

The VITA system will consist of more than 500 ground stations, at a cost of $4000 to 6000 each. Ground stations will be in view of a satellite twice a day for 12 minutes per pass. During this time, the station can transmit between 50 and 380 pages of text. VITA anticipates using the system for disaster relief, medical information sharing, and to collect health epidemic data.

Constellation Communications Inc. (CCI) has filed an application with the FCC to construct a satellite system based on 48 LEO satellites. This global system, called Aries, only

Constellation Communications Inc. (CCI) has filed an application with the FCC to construct a satellite system based on 48 LEO satellites. This global system, called Aries, only uses 5 MHz of bandwidth in the RDSS band, allowing for competition and hence lower rates for users. System costs are estimated at $292 million, with the breakeven point at 100,000 subscribers.

Each Aries satellite will weigh 275 pounds and have a 5-year design life. The earth segment will consist of a single ground control station, a network of gateway earth stations, and subscriber terminals, both mobile and handheld. Subscriber terminals are expected to cost less than $1500. Services will include two-way voice, one-way voice (dispatch), data, facsimile, and position determination and reporting.

Ellipsat Corporation is fielding a system of 24 lightsats called Ellipso II. Total system costs are estimated at $214 million. Each satellite will weigh 150 pounds and be one of six in an elliptical orbit plane. Ellipso will use CDMA techniques to be compatible with digital cellular systems now being tested, with the goal of providing "seamless" transparent roaming between terrestrial and satellite services. Ellipsat will not market services directly to consumers, rather they will market to companies that provide enhanced services to subscribers, such as cellular companies.

Leosat, under development by Marcor, Inc., is designed to be a worldwide digital satellite-based communications system providing end users with two-way data channels for smart car electronic systems, intelligent vehicle/highway system monitoring, pollution control, and remote equipment monitoring. Leosat radios will cost between $50 to 200, and occupy 1 MHz of bandwidth in the VHF band (150 MHz). Leosat satellites will operate in a 40° inclined orbit at 970 km (600 miles). Eighteen satellites, each costing $700,000, will be launched at a cost of $500,000 per launch.

Loral Cellular Systems Corporation, formed by Loral Aerospace and Qualcomm, plans to construct Globestar, a constellation of 24 satellites added for domestic coverage in the 1997 time frame, with an additional 24 satellites added later for global coverage. Loral expects to spend $657 million to build and launch 24 spacecraft with eight ground spares. Five thousand subscribers could use the 24-satellite system simultaneously, and the 48-satellite constellation could support 100,000 users worldwide.

Globalstar will use spread spectrum multiple access (SSMA) techniques, along with six spot beams for a frequency reuse factor of 288. The system will interoperate with the PSN, existing cellular networks, private networks, and personal communications networks, providing users with global RDSS and mobile voice and data services.

The most complex satellite-based system is being developed by Motorola. With total system development costs expected to be around $3 billion, Iridium's network of 66 small satellites will allow portable cellular telephone users to communicate anywhere on land, sea, or air. The original 77-satellite design was to have cells 372 nm in diameter and be able to handle 100 users in 10.5 MHz of spectrum. Five types of Iridium services planned are: geopositioning and two-way messaging, digital voice communications, facsimile, data transmission, and global paging. Full service is scheduled to begin in 1996. Each Iridium phone will be dual-standard: one mode for domestic compatibility and a second, global Iridium standard. Iridium will use 16 MHz of spectrum initially, enough to support 2.5 to 4 million users. GE has agreed to develop software for the Motorola project, joining Lockheed, Hutchison Telecommunications of Hong Kong, and British Aerospace. GE will develop workstation software for network operations and satellite control.

By its nature, Iridium is a higher-priced, lower-density service than conventional cellular telephone. Initial handheld units are expected to cost $3000, with the price dropping to $1000 as the number of units increases. Available features are expected to include call waiting and forwarding, call conferencing, caller ID, and the ability to provide GPS position data. Phones can have pagers and voice mail, along with a toll-free 800 number to retrieve messages. Service rates are projected to be $3 per minute for outgoing calls, with a monthly service charge of $50.

Norris Satellite Communications has applied to construct a satellite to operate at Ka-band (30/20 GHz). Called NorStar I, the satellite will provide fixed, broadcast, mobile, and personal communications services to the continental United States. With a design life of 10 years, the satellite is planned for launch in 1994 with an orbit at 90°W. Norstar I will cost $190 million, including a spare satellite, launch costs, and insurance. Funding will come from the sale of transponder capacity. If the FCC approves Norris' approach, Norstar will be the first U.S. commercial satellite operator to provide service at Ka-band.

Orbital Sciences Corporation has also petitioned the FCC to allocate spectrum for a LEO global MSS, Orbcomm, which will also provide limited positioning data. Global coverage will come through the use of 20 small satellites, two in polar orbit and six each in three 40° inclined orbit planes. The system would handle short (30 character) data packets compatible with the X.25 protocol standard.

OrbComm's first satellite is scheduled to be launched in 1993. Each satellite will have a design life of 7 years, and will be launched using OSC's Pegasus booster. Full system operation will be in the 1994 time frame. Projected system costs are $283 million. Services will be marketed to auto clubs, insurance companies, oil companies, environmental groups, and container services for intermittent poll messaging. The lightweight, low-power pocket size terminals should be priced between $50 and $350 for 2- to 5-watt units. Data packets will be about 50 letters and numbers, each burst lasting 1/10th of a second. Satellites will pass overhead eight times per day, in view for 10 minutes each pass.

Qualcomm Inc. is the only MSS service provider in the United States to use Ku-band and thus does not have to compete for limited RDSS band (1610-1626 MHz [L-band], and 2483 to 2500 MHz [S-band]) spectrum. Using existing satellites should enable the company to save millions on satellite system construction and launch costs. Qualcomm's OmniTracs is a satellite-based mobile communications system providing two-way messaging and positioning data between truck fleets and dispatch centers.

Radio Satellite Corporation (RSC) has applied to the FCC to provide nationwide radio communications and position determination services to cars, trucks, and other vehicles. RSC plans to lease capacity from AMSC, then resell that capacity to broadcast, paging, and mobile communications companies. RSC is developing a mobile radio system capable of alphanumeric paging, digital audio, and data broadcasts. The radio can support two-way voice messaging. A keyboard is required for two-way data messaging. System development costs are expected to be in the $3 to $5 million range.

Satellite CD Radio is a joint venture of Marcor, Stanford Telecom and Ingenico of France, formed to deliver 100 channels of CD-quality digital audio to car radios across the United States. Marcor developed the hardware and will manage the acquisition of the satellite and radio equipment. Satellite CD Radio will downlink in the 2310 to 2360 MHz band, with an X-band (7045 MHz) uplink. Project costs are estimated at $350 to $400 million, with satellites available in 1996/1997, assuming FCC approval.

Starsys Inc. has applied to construct 26 LEO satellites to provide spread-spectrum mobile satellite services. The system, called Starnet, will be composed of 24 in-orbit satellites and two ground spares. In 1300 km orbits inclined at 50° to 60°, the system will use 1 MHz of bandwidth in the 137 to 138 and 148 to 149 MHz bands. Spread spectrum modulation will allow mobile units to share frequencies.

The Starnet system is projected to cost approximately $300 million. Services will include two-way communications and position determination services via portable transceivers costing less than $75. These calculator-sized terminals will provide interconnection with the PSN, worldwide position determination, emergency alerts, environmental monitoring services, antitheft services, pollution monitoring, and biosensor monitoring.

TRW has entered the MSS market with an application to launch a 12-spacecraft RDSS, cellular phone, data, and messaging services satellite system, called Odyssey, by 1996. Four satellites will be in each of three orbital planes inclined at 55°, all at an altitude of 5600 miles. TRW plans to use CDMA spread-spectrum techniques. Gateway-to-satellite links will use 220 MHz of spectrum at Ka-band. User uplinks and downlinks will be in the L- and S-bands, respectively. The Odyssey system will connect any two handheld portable subscriber units, or provide interconnection to the PSN through either of two gateways. System capacity will be about 4600 simultaneous users.

Globalstar will consist of 24 to 48 satellites at 1500 km, meaning the satellites will orbit the earth once every 2 hours. This constellation will provide capacity for 60,000 to 104,000 simultaneous two-way conversations anywhere in the world. Unlike other MSS systems, the Globalstar satellites will be relatively dumb, with system "smarts" and the PSN interface contained in base stations located between 250 to 400 km apart.

INTELSAT's Project 21, due to be fully operational by the year 2000, will directly challenge Motorola's Iridium system for market share. Intelsat expects to spend between $500 million and $1 billion on system development costs, saving money by adapting today's cellular technologies, and using existing satellites. The mobile units would sell for less than $1000, with call costs around $1 per minute.

Barton and Norbury have developed the concept of a "picoterminal" for portable use with MSS systems. About the size of a romance novel (10x20x4 cm), these picoterminals would send data traffic at less than 200 b/s via a 10-cm square antenna and a power output of about 1/2 watt. By using 20/30 GHz transponders on GEO satellites, several thousand picoterminals could network simultaneously.

An enabling technology for MSS is the continued development of several types of medium-gain, circularly-polarized, mobile L-band antennas. Two types of antennas have been successfully deployed: the electronically-steered planar phased array and the mechanically steered tilted microstrip patch array, both developed through the Jet Propulsion Laboratory. The phased array has a low profile (less than 1 inch) but has a high manufacturing cost. The mechanically steered array costs about $600 to make, but stands about 6" tall. To overcome the cost and profile hurdles, JPL has developed a mechanically-steered planar microstrip Yagi array. The manufacturing costs are expected to be around $450 per unit. Major cost components are dielectric circuit board material, open-loop angular rate sensor, pancake motor, rotary joints, and assembly labor.

4.5.3 Deployment

Factors of Supply

Several issues stand in the way of industry's response to users' demands for mobile services. Domestic and international regulation of telecommunications services and providers will probably be the gating function for mobile services growth. A second issue is compatibility of mobile systems with existing terrestrial systems and networks. User costs, both recurring and nonrecurring, will also dramatically affect growth in mobile services. As more companies scramble for a piece of the pie, increasing competition will cause some instability in the market as the players come and go. Fixed plant telecommunications systems typically have high initial capital outlays; system financing will also be a significant issue for mobile services providers. Major technical constraints on MSS systems are small terminal size, low cost, and adequate gain.

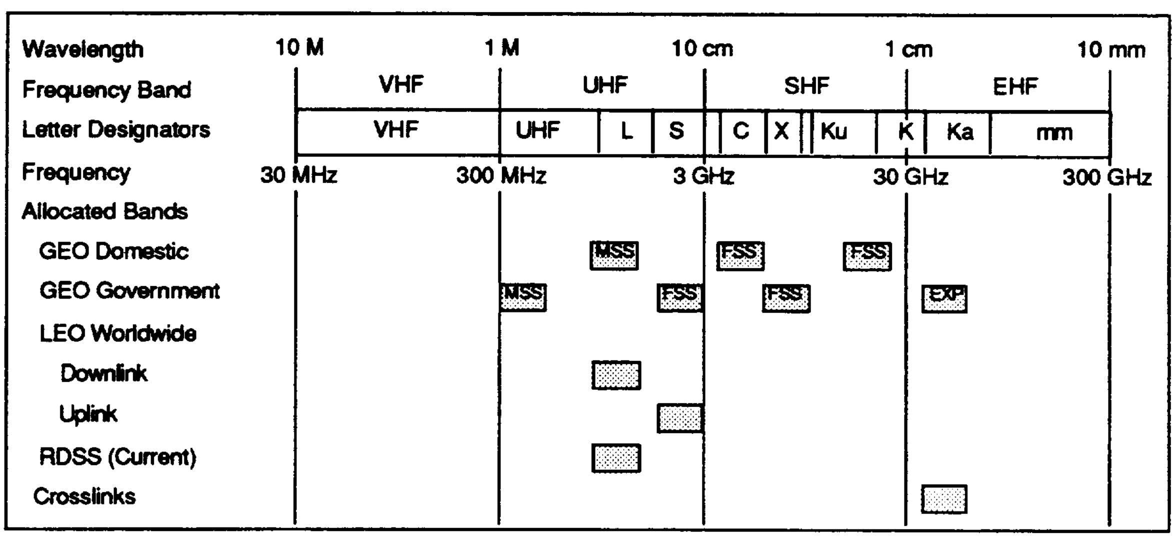
A major factor limiting growth in the provision of MSS is the lack of available spectrum in the 1 to 3 GHz (L and S) bands. Because the FCC received 12 applications for basically 33 MHz of spectrum, the FCC decided there should be only one MSS licensee, AMSC. Recent court challenges have failed and the FCC decision to grant this monopoly stands, although three new companies were allowed to join the AMSC consortium.

The scarcity of spectrum for RDSS and MSS systems was addressed this year in Torremolinos, Spain at WARC '92. A summary of WARC '92 Allocations (all frequencies in MHz; effective 12 October 1993) is as follows:

<u>LEO</u>		
Above 1 GHz	Worldwide Primary	1610-1626.5 uplink 2483.5-2500 downlink
Below 1 GHz	Worldwide Primary	137-137.025 137.175-137.825 400.15-401 149.9-150.05
	Worldwide Secondary	387-390 312-315 137.025-137.175 137.825-138
<u>GEO</u>		
MSS	Worldwide Primary	1980-2010 uplink 2170-2200 downlink 2500-2520 2670-2690
	Worldwide Secondary	1930-1970 uplink 2120-2160 downlink
Maritime MSS	Worldwide Primary	1530-1544 downlink
	Region 1 Primary	1525-1530 downlink
Land MSS	Worldwide Primary	1525-1530 downlink
	Region 2 Primary	1492-1525 downlink

Figure 4-76 illustrates the frequency bands allocated to various services.

FIGURE 4-76
Radio Frequency Spectrum Used By Satellites



Source: The Aerospace Corporation

Besides the spectrum allocation issues, another supply-limiting factor is the plethora of regulations and regulatory agencies involved in fielding a global telecommunications system.

Inmarsat has solved the international border crossing problem by negotiating agreements that allow mobile units to cross borders without interference from customs or radio regulatory enforcers.

Motorola has designed geolocatability into its terminals so they can tell where each call originates. This allows the system to block a call if a particular country does not allow Iridium services. In discussions with 33 countries, none has indicated it would not allow Iridium terminals to operate within its borders.

Both wide and local area wireless data communications will benefit from technology advances, such as spread spectrum modulation. Other advances, including personal communications networks and digital cellular telephones, should greatly reduce the cost of parts and service fees for nonvoice transmission.

Factors of Demand

The telecommunications industry has a significant business opportunity in wireless communications. The overall market for wireless communications is expected to grow more than 375 percent between 1990 and 1993. Within the next 5 years, the industry will be well on its way to "fiber to the home," a development driven by the increased bandwidth required to network computers in the home and office. As people become more reliant on telephone systems for both voice and data connectivity, they are also demanding freedom from fixed-plant, wireline systems. Hence the recent tremendous growth in the cellular telephone industry. As the cellular phone has allowed mobile voice services, demand has increased for a similar capability for data transfer. Roaming by cellular telephone users is expected to drive demand for PSN access in remote areas. AMSC says that by 1995 90 percent of the U.S. population will be covered by cellular or MSS systems, but 50 percent of the landmass won't be covered.

The largest demand-limiting factor is the price of user terminals and monthly service charges. With some MSS systems costing billions of dollars to develop, developers must not rush to recoup their costs, thereby driving up user fees. Projected user terminal costs for MSS systems are on the order of $75 to $1000, while service charges from $1 to $3 per minute have been projected by some MSS vendors.

As companies move to reduce costs and improve productivity, MSS demand will rise. Enno Jacobson, director of risk management at Challenger Motor Freight in Ontario, Canada, says that MSS has reduced the number of calls from drivers to dispatchers by 70 percent, and cut its long-distance bill by 40 percent. Productivity gains have been even greater.

Intelligent vehicles/highway systems (IVHS) will rely on satellites for vehicle tracking, traffic management, and vehicle location. Federal funding for IVHS research totals $659 million: $94 million in FY92 and $113 million per year for fiscal years 1993 through 1997. IVHS program goals are to reduce travel times in congested areas up to 50 percent, reduce auto pollution up to 15 percent, and reduce gasoline consumption up to 10 percent.

The industry consensus is that MSS will experience tremendous market growth during the period of this study. The U.S. mobile satellite services market was $165 million in 1990, and is expected to grow to $2.7 billion by 1994. John Pemberton of the Gartner Group predicts that the current $370-million market for mobile satellite services will grow to $6.2 billion by 1995.

IRD, a market research firm, predicts the market for MSS will reach $1 billion by 1995 and $9 billion by the end of the century; the initial target market is luxury car buyers, truckers, limousine operators, and RV users.

4.5.4 Cost

Revenues from cellular telephone equipment sales were estimated at $2.8 billion, an 8-percent increase over 1990. Estimated service revenues were $5.5 billion in 1991, a 17 percent increase over 1990. Roaming outside the home cellular area accounted for 11 percent of the service revenues. By late 1991, the number of cellular subscribers had grown to about 7.4 million. The average cost of cellular service declined to an average of about $75 per month, and the average cellular call lasted 2.4 minutes.

Motorola says the U.S. market is not large enough to support a dedicated mobile system, so any MSS would necessarily have to be global to be economically viable.

System Development Costs

The VITA system will consist of more over 500 ground stations, at a cost of $4000 to $6000 each. CCI estimates Aries system costs at $292 million, with the breakeven point at 100,000 subscribers. Ellipso II total system costs are estimated at $214 million. Leosat's 18 satellites, each costing $700,000, will be launched at a cost of $500,000 per launch. Loral expects to spend $657 million to build and launch 24 spacecraft with eight ground spares.

Iridium's total system development costs are expected to be around $3 billion. Norstar I will cost $190 million, including a spare satellite, launch costs, and insurance. Projected system costs for Orbital Science's Orbcomm system are $283 million. Orbcomm estimates its investment in its two-satellite experimental system at $20 million. Radio Satellite Corporation estimates its system development costs to be in the $3 to $5 million range. Satellite CD Radio project costs are estimated at $350 to $400 million.

Starsys's Starnet system is projected to cost approximately $300 million. Intelsat expects to spend between $500 million and $1 billion on system development costs, saving money by adapting today's cellular technologies and using existing satellites.

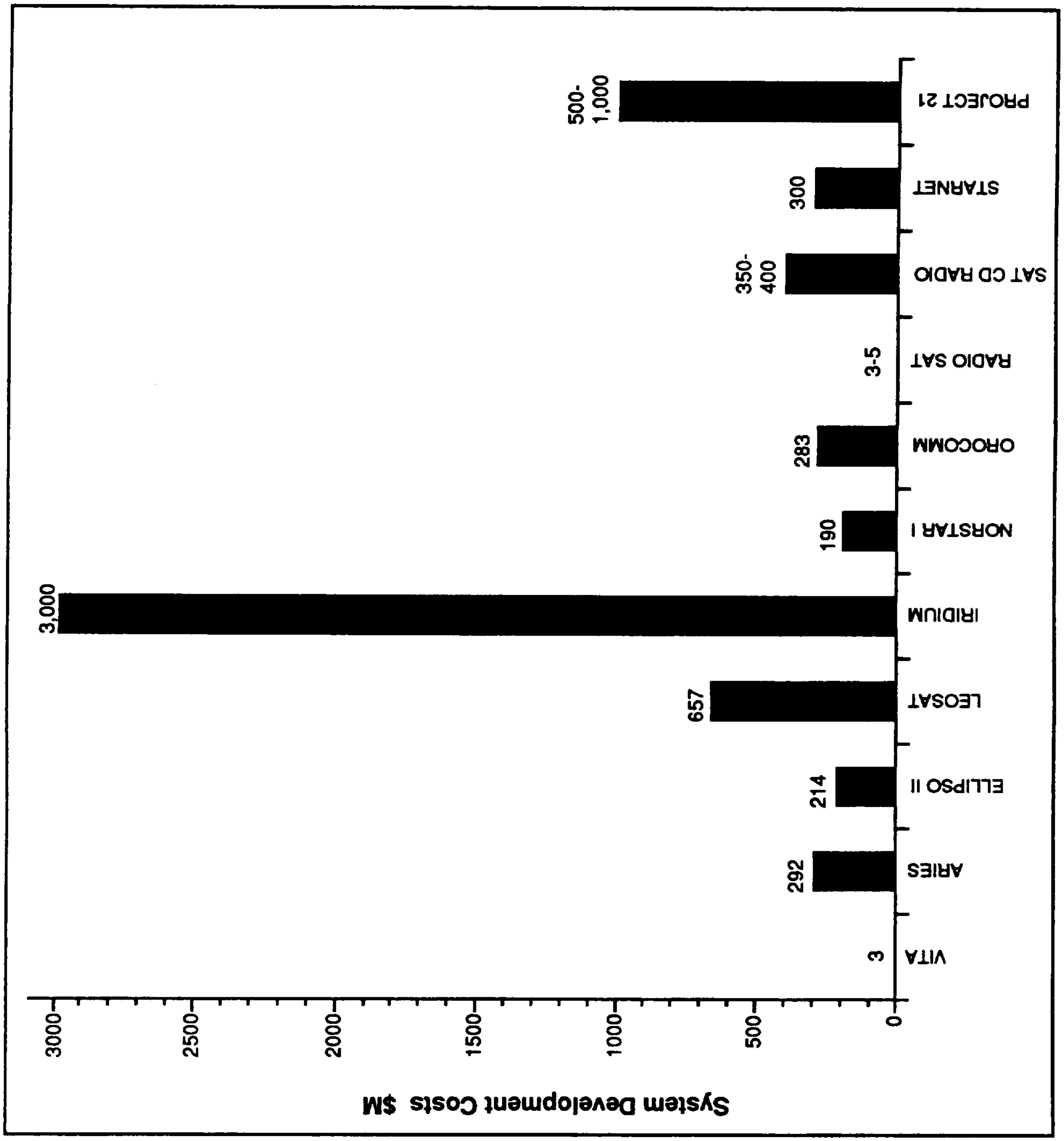
System development costs are summarized in figure 4-77.

Equipment and Service Costs

INMARSAT terminal costs declined to about $30,000 each in 1991. Mobile units for the AMSC system are projected to cost $3000, with monthly service charges in the $80 range. Users will be charged about 82 cents per minute for services including two-way voice communications, mobile facsimile, PSN access, private networks and vehicle tracking. CCI estimates Aries subscriber terminals to cost less than $1500. Leosat radios will cost between $50 and $200 each.

Iridium handheld units are expected to cost $3000, with the price dropping to $1000 as the number of units increases. Service rates will be $3 per minute for outgoing calls, with a monthly service charge of $50. Orbcomm's lightweight, low-power pocket-size terminals should be priced between $50 and $350 for 2 to 5 watt units.

FIGURE 4-77
System Development Costs



Starnet services will include two-way communications and position determination services via portable transceivers costing less than $75. Intelsat Project 21 mobile units would sell for less than $1000, with call costs around $1 per minute.

Mobitex service pricing includes basic charge of $15 to $30 per unit per month, with a per-packet charge of 3 to 12.5 cents based on packet size. CoveragePLUS terminal units are $2000 to $4000, versus $4000 to $4500 for Geostar and Qualcomm. Monthly charges per unit are $35 plus 5 cents per 240-character message.

4.5.5 Traffic

The U.S. Department of Commerce projects that the market for radiodetermination services will exceed $1 billion annually by the late 1990's. Motorola expects that more than 3 million subscribers, more than half the subscriber base, will use RDSS, paging, and messaging services. More than 310,000 long-haul trucks are expected to use Iridium for vehicle tracking and two-way messaging. The international market is projected at more than 1.2 million users for truck tracking services.

Iridium will use 16 MHz of spectrum initially, enough to support 2.5 to 4 million users. Worldwide, Motorola expects 6 million subscribers by 2001 (1.3 million in the United States). Total addressable market for all types of Iridium applications is estimated to be 30 million in the United States alone. Recent estimates of the number of Iridium users stand at 100 million worldwide by the year 2000. RDSS and two-way messaging services to truckers will account for 25 percent of the total subscriber base. Global paging would represent another 25 percent of the total, with the remainder split among remote sensing, mining and drilling, and business aircraft applications.

The estimated paging market in the United States for the year 1997 is expected to exceed 23 million users; the vast majority of these will be local and regional pagers. Global paging use will be most prevalent among the 50 million business persons travelling abroad each year. Motorola estimates that, assuming a 3 percent penetration rate, there will be nearly 1.5 million global pager users among business persons traveling in foreign countries, with 300,000 additional users in the United States. Inmarsat expects to offer a satellite direct paging service by 1994.

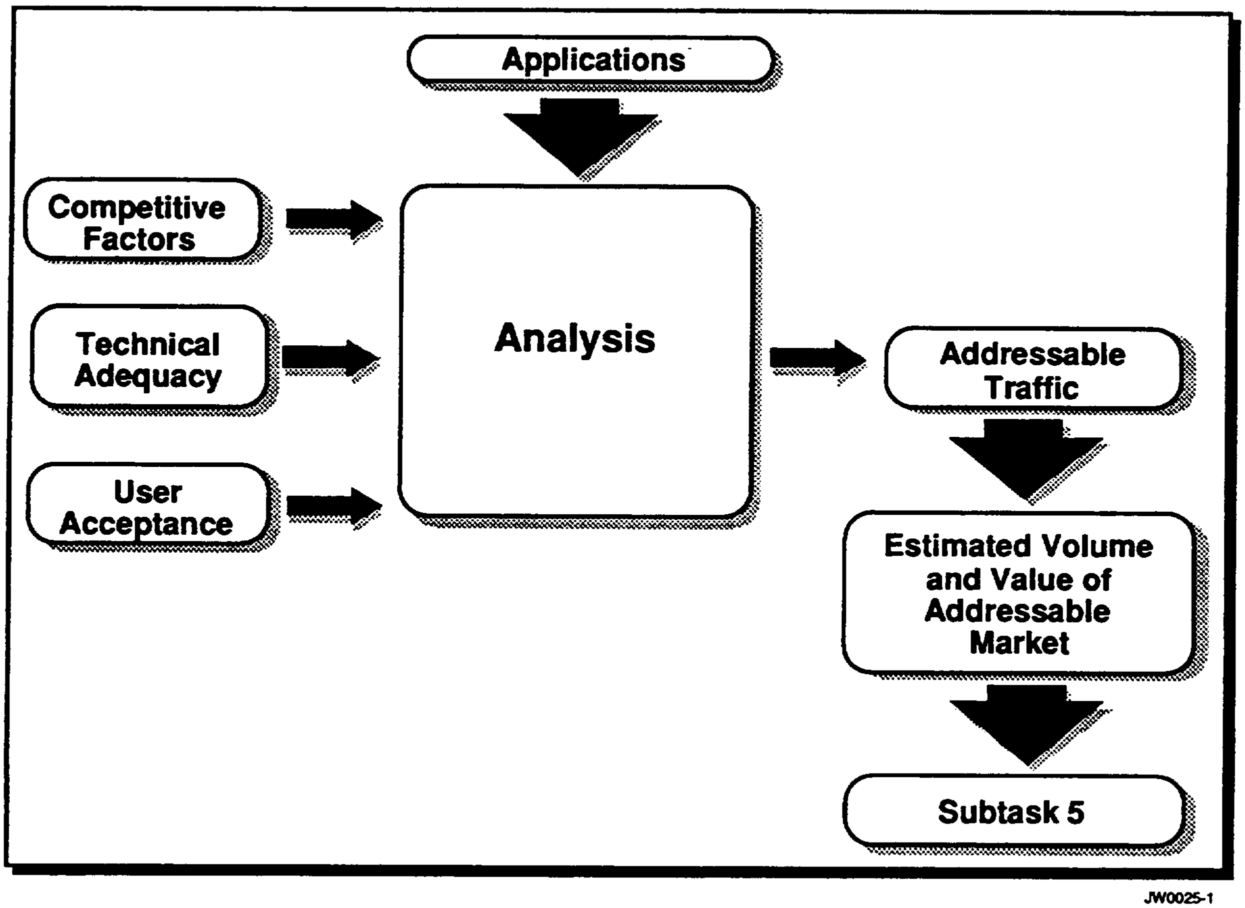
With 18,800 maritime satellite terminals in use in 1991, the industry is projecting better than 25 percent annual growth, with 232,000 terminals in use by 1995. INMARSAT-compatible aircraft terminals were installed in 40 aircraft in 1991; projections are for 3,500 terminals compatible with INMARSAT installed by the year 2000. Sources estimate that 20 percent of all cellular traffic will be facsimile by 1995, and data traffic will exceed voice by the year 2000. Odyssey system capacity will be about 4600 simultaneous users. The Globalstar constellation will provide capacity for 60,000 to 104,000 simultaneous two-way conversations anywhere in the world.

Although the industry consensus is that MSS will experience rapid market growth, traffic projections for this application are not provided in this section due to service user uncertanties. Additionally, other technologies that may affect MSS market share such as PCN and advanced intelligent networks are still in their development stages, thus preventing complete analysis. Industry estimates generally support the optimistic outlook for MSS; for example Motorola projects the potential market for MSS in the United States at 30 million subscribers, 10 million of which do not have cellular coverage. Additional factors pertaining to MSS traffic projection are discussed in section 6.0 of this report.

5.0 SATELLITE-ADDRESSABLE MARKETS

The objective of this subtask is to identify the portions of traffic derived in section 4 that could be served by satellite technology. To accomplish this subtask, it is necessary to analyze each application group and its constituent technologies along three interrelated dimensions: technical adequacy, competitiveness, and user acceptance (NASA 1992). Figure 5-1 summarizes this approach.

FIGURE 5-1
Determining Satellite-Addressable Markets



Technical Adequacy refers to the ability of a technology or service to meet the technical communication requirements of an application. In general, a technology or service is considered to be technically adequate for an application if it has a significant installed base. A technology that has not yet been introduced or is too new to have developed an installed base is considered technically adequate on the basis of sound engineering and marketing judgment. Examples of criteria for technical adequacy are bandwidth, error rate, and effect of transmission delay.

Competitiveness is defined in this analysis as the potential for a technology to become a substitute for other means of providing a communication service. For a satellite service to be competitive in a market, it must be able to capitalize on its strengths—where it offers an advantage over other means of providing services—such as wide geographic coverage, low operating and equipment costs from economies of scale (cost leadership), ease of node mobility, and service reliability.

To evaluate competitiveness requires identifying the competing technologies and the level of competition among companies in the industry segment being examined as well as those companies in other segments that will provide competing technological solutions. For instance, VSAT manufacturers and service providers compete directly with leased-line and software-defined network providers because these are three alternatives for private networks. These providers are two different segments of the same private communications market. Factors such as barriers to entry, rivalry among companies, and bargaining power of customers and suppliers affecting the relative competitiveness of different industry segments are also discussed.

User Acceptance has both an objective and a subjective component. Examples of objective criteria are zoning or safety restrictions on satellite or microwave installations. Examples of subjective criteria are ease of use (i.e., user friendliness) and subjective judgments of transmission quality. The prominent example of the latter is voice transmission through geosynchronous satellites. In the early 1970's, geosynchronous satellite transmission of voice over long distances provided better transmission quality (i.e., higher signal-to-noise ratio) and was cheaper than microwave transmission. These advantages were generally considered to outweigh the deleterious subjective effects of the half-second round-trip transmission delay, especially for leased lines or private networks, where the user community could be trained to use satellite circuits effectively. Beginning in the mid-1980's, single-mode fiber optics erased both the quality and cost advantages of satellite communications over the coterminous United States. Consequently, satellite communications no longer had any advantage that compensated for the subjective effects of transmission delay, and (geosynchronous) satellite communications began to be judged unacceptable for voice. This example illustrates the general context dependence of the user acceptance factor. It also illustrates the interworking of technical and cost factors in determining user acceptance.

Estimates of satellite-addressable traffic were derived from the estimates of potential traffic supplied in section 4 for each application. These data were modified by a satellite addressability factor to determine the amount of traffic that could be addressed through satellite means. The total traffic volume for each application is multiplied by a representative figure for the average cost of a terrestrial DS0 equivalent. We used a fractional T1 circuit as a proxy. The annual cost was computed as the average of a 50-mile circuit and a circuit between Washington, D.C., and San Francisco (2,400 airline miles) using MCI tariffs. As part of this calculation, we included a 10 percent discount from published tariffs for the effect of volume purchases and multiyear contracts, resulting in an annual cost of $6,180 per DS0.

5.1 BROADBAND ISDN

Section 4 examines three broadband services: frame relay, SMDS, and BISDN. For the purposes of this section, we examine these as a single entity by using the term "broadband ISDN" to refer to all three of these services unless otherwise indicated. Although actual BISDN is not yet commercially available, some carriers offer frame relay and SMDS, and the availability of these services is increasing. Although differences among these three services are noted in section 4, the general industry view is that BISDN will eventually supplant frame relay and SMDS for many applications. Eventually, it is possible that the whole PSN will migrate from today's circuit-switched architecture to a packet-switched architecture based on BISDN using ATM or a successor. Such a migration would transform the PSN from parallel switched networks for voice and data to one wherein voice, data, and video are treated uniformly, albeit perhaps with a priority structure, within a single public switched network.

5.1.1 Technical Adequacy

Satellite technology could play two qualitatively different roles in BISDN. On the one hand, satellites could play the central role in a BISDN network, providing both the switching and the transmission. Capacity constraints on satellites would preclude their forming the heart of the public BISDN network, but networks serving a closed user community could be based on satellite technology. On the other hand, satellites could play a peripheral role in a BISDN network, providing some transmission paths between switches. In one case, both switches could be part of the public BISDN network. In the other, more likely, case, one switch would be a dedicated customer-premises BISDN switch, and the other would be a public BISDN switch. This would allow the extension of switched broadband service to users who were too remote from population centers for optical fiber transmission to be economical.

For either of these situations, satellites already are technically capable of providing the transmission paths. Geosynchronous satellites are configured with transponder channel bandwidth of 40 MHz or larger, supporting transmission rates in excess of 60 Mb/s. Because a properly engineered satellite link provides a very low bit-error rate, very little overhead would be taken by error correction, using either forward error correction or error detection with retransmission. Thus, a source-to-source bit rate on the order of 60 Mb/s or higher would be adequate for BISDN.

For a private BISDN network in which satellites play a central role, broadband switching will be required. It is unavailable on commercial satellites. NASA's ACTS program will demonstrate the engineering feasibility of high-bandwidth satellite switching. Thus, satellites launched around the beginning of the 21st century could have the switching capability required to support BISDN networks.

An issue related to technical adequacy is the effect of satellite delay on storage requirements for packet transmission. Because a packet must be stored at the source until its correct delivery can be assumed or confirmed, the storage requirements rise with network delay. However, because the cost of memory is low and is continuing to decrease, this should not be a problem.

Another technical adequacy issue is the effect of satellite transmission delay on the operation of the BISDN network management system. The T1S1.5 ATM Subworking Group, which is studying proposed standards for congestion control algorithms, is investigating the effect of increasing the minimum packet delay time from a few tens of milliseconds to about a quarter of a second.[1] Because this work is ongoing, this report assumes that a satisfactory resolution will be found for this problem.

5.1.2 User Acceptance

To characterize user acceptance, it is convenient to divide BISDN applications into three categories:

- Voice only—ordinary voice calls or those with accompanying low-data-rate video
- Voice plus video—voice calls with accompanying high-resolution video that requires a high data rate

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1 Other groups studying the role of satellites in BISDN are CCITT Study Group XVIII, Working Party VII, CCIR/CCITT ISDN/SAT (Joint Ad Hoc Group), and CCIR Working Party 4B.

- Other—data and those high-resolution video applications in which person-to-person conversation is not a major factor; this includes video conferencing.

For the first category, the present human factors objections to the half-second round-trip delay for voice transmission through geosynchronous satellites would probably mean that a communications manager would use terrestrial circuits for voice rather than combine the voice traffic onto a BISDN satellite service or link. Looking ahead to widespread availability of ISDN and fractional T1 service, it would not be difficult to accommodate a voice conversation with accompanying low-resolution video that required only 2 or 3 DS0s.

For the second category, if there were no terrestrial alternative to carry this traffic, it would be put on a BISDN satellite link, if one existed, and the users would probably accept the accompanying delay. If there were a terrestrial alternative for this specific traffic, for instance SMDS, the communications manager would have to evaluate the loss in subjective quality by using the satellite BISDN link versus the assumedly higher cost of using the terrestrial alternative to BISDN. One important factor in this evaluation would be whether there was other traffic, from the third category above, that necessitated a satellite BISDN link. If so, the attendant economies of scale would make it even harder to justify terrestrial links for the conversation traffic. In summary, satellite BISDN communication would be competitive for this category of traffic, with the result depending on particular circumstances and costs.

For the third category of traffic, there should be no user acceptance issues for satellite BISDN. Video conferencing is included in this category of traffic because the complexities of interacting in a group and the typical voice-actuated camera switching tend to impose a "push-to-talk" discipline on the participants very similar to that required to deal with satellite delay on an ordinary voice call.

5.1.3 Competitiveness

Section 5 notes that a satellite service's competitive posture rests on one or more particular strengths, such as wide geographic coverage, low cost, ease of node mobility, or reliability. Since the underlying transport mechanism of BISDN requires very high bit-rate transmission, which can be provided terrestrially only by fiber optics, an important competitive strength of satellite BISDN service is that sufficiently high bit rates can be provided to any location in the beam footprint.

An organization considering a private BISDN network should examine the availability of adequate bit rates on the trunks between the BISDN switches and on the tails from the B-ISDN switch(es) to the user locations. A satellite's ubiquitous access offers no particular advantage for interswitch trunks, because any wide-area BISDN network can locate most or all of its switches near major population centers, all of which are connected by fiber optic cables by the major carriers. Satellites would provide an advantage in situations where many of the user locations did not have wideband access to the locations proposed for the network's BISDN switch(es). It seems likely that an important issue would be whether the preponderance of locations did or did not have such access. If they did not, the uniformity and simplicity of an all-satellite system, with a single on-board switch, would be very attractive. If most locations had wideband access to possible terrestrial switch locations, use of satellites only to connect the outlying locations into the network would become relatively more attractive.

Of course, a hybrid architecture could also be considered. This could entail a satellite BISDN switch plus one or more ground-based switches. Outlying locations would be connected to each other through the satellite, locations with wideband terrestrial access would be connected to each other through the ground-based switch(es), and an outlying location would be connected to a location with wideband terrestrial access through tandem switching using the satellite and one or more ground-based switches.

Evaluation of these kinds of candidate architectures would require consideration not only of cost but also of the timeframes in which user locations had to be connected to the network and the timeframes in which wideband terrestrial access might be available.

For a carrier with an established terrestrial public BISDN network, a satellite link would be considered only if there were a business opportunity that could be met only by extending the network into a remote area. In this case, a satellite link from a single user location to an existing BISDN switch or a satellite link from a remote BISDN switch serving several customers would be a solution that should be considered.

5.1.4 Evolution to BISDN

Frame relay and SMDS are considered the precursor transmission media for the wideband digital services that can be offered through BISDN. Consequently, the previous discussion of technical adequacy, competitiveness, and user acceptance of BISDN is applicable to frame relay and SMDS. Frame relay and SMDS compete directly against leased lines and X.25 packet data networks. With more than 90 percent of the data communications market share, leased lines have a very strong competitive position in the market. Whereas leased lines provide full-time dedicated communication links, services such as frame relay, switched T1, and SMDS provide occasional-use, high-bandwidth communications. Usage-based pricing of frame relay and SMDS has the potential to significantly broaden the market base for these communications services.

5.1.5 Traffic Estimates

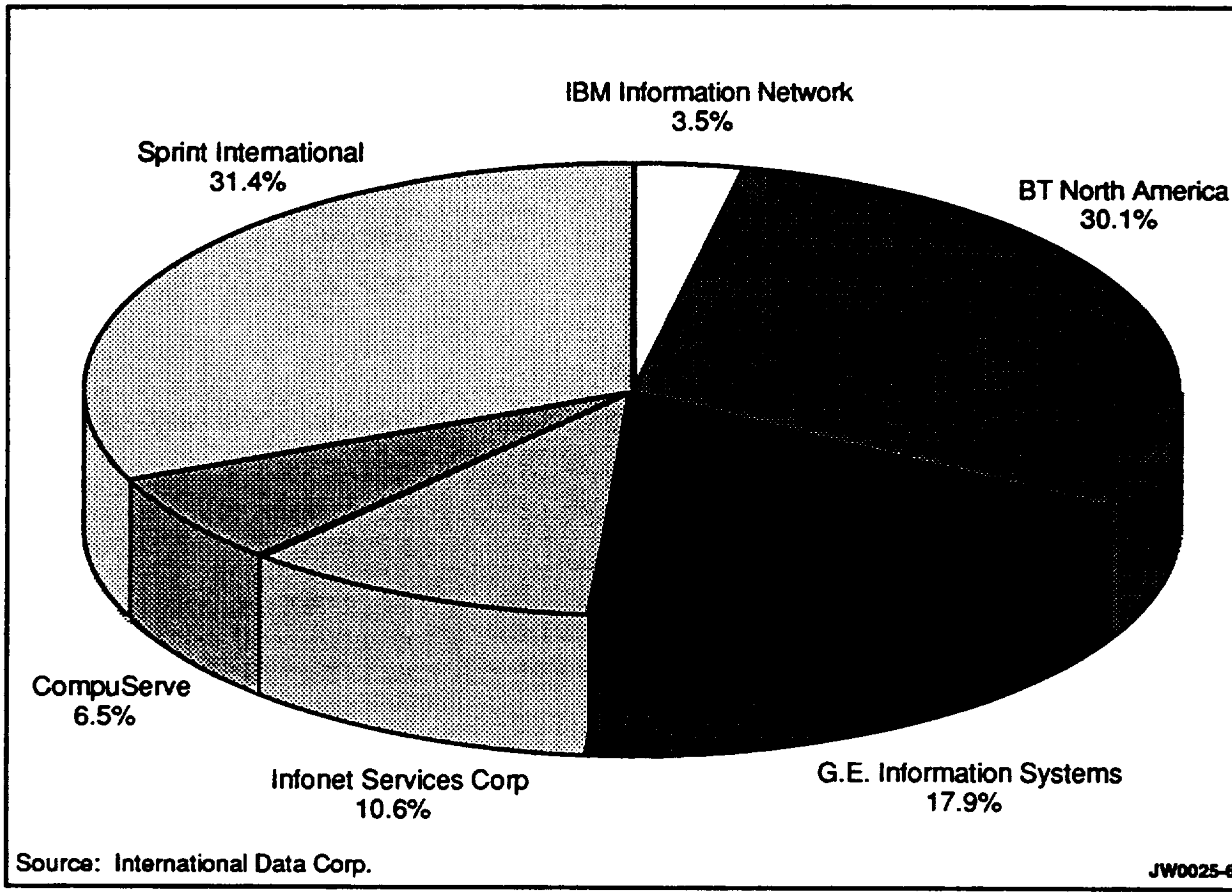
The competitive nature of the data communications industry is a factor that favors consumers and supports the long-term penetration of broadband ISDN. As figure 5-2 illustrates, the market for value-added network services, of which broadband transmission is a part, is dominated by several commercially powerful carriers. In addition, major interexchange leased-line carriers such as MCI, AT&T, and WilTel are already offering frame relay services. The competitive nature of the long-distance market is spurring rapid implementation of frame relay services, with 11 companies offering it or planning to offer it in the near future.

On the other hand, SMDS, which is an LEC-provided service, has not been implemented by the LECs as rapidly as the IECs have introduced frame relay. For SMDS, this is probably due in part to the lack of competitive pressure rather than a lack of potential markets. This may be changing soon. Several interexchange carriers are now experimenting with SMDS as the next step in the evolution of a national broadband network. Experts believe that success of SMDS depends largely on its support by the IECs; otherwise, SMDS will be confined to local access and transport areas.

BISDN is far less close to commercial reality than frame relay and SMDS. Standards are still under development, and the first ATM switches are just beginning to reach the market.

Because broadband ISDN is still in the product introduction stage, where customer awareness is being created, user acceptance of BISDN is low. However, broadband applications should eventually receive a high level of user acceptance as high bandwidth services (e.g., video dialtone) become more popular. Moreover, remote users may consider satellite as the first choice over terrestrial means because of its easier and often less expensive deployment.

FIGURE 5-2
Value-Added Network Service 1991 Market Shares



The market for data communications services is expected to reach approximately $10 billion in 1992, a 10 percent increase over 1991. In 1992, packet switching, frame relay, and SMDS in total will account for an estimated 7 percent of the total data communications market in terms of service revenues (Wilde January 1992)

Figures 5-3, 5-4, and 5-5 summarize the estimates of traffic volume and value for frame relay, SMDS, and BISDN in increments of 5 years for the period 1991 to 2011. The only potential use of satellite to provide BISDN access would be for those users not having access to high-speed data communications and who, because of their geographic isolation, would not likely acquire terrestrial access in the future. To determine this amount, we estimated the number of research network users who do not have terrestrial circuits available to them. For instance, NSFNET estimates that 1 percent of their entire user base does not have access to terrestrial T1 circuits. Because these users are representative of the potential market for satellite BISDN, we use the NSFNET example as a proxy for computing total BISDN addressability through satellite.

Figures 5-3, 5-4, and 5-5 present the detailed estimates for each application by traffic type. As noted in the figures, these estimates are one percent of the estimates in figures 4-12, 4-22, and 4-37. Since the estimates in section 4 represent non-overlapping markets, so do the estimates in figures 5-3 through 5-5.

It can be noted that the demand shown in figures 5-3, 5-4, and 5-5 is much smaller than the VSAT demand shown in figure 5-6. The reason for this difference is that, for the most part, present VSAT systems address different markets than frame relay, SMDS, and BISDN. Figure 4-2 shows the range of data rates for these three broadband services. SMDS is from 1.5 Mb/s up to 45 Mb/s, well above the capability of most of today's VSAT systems. Frame relay is "up to 2 Mb/s," but its principal driver (see section 4.2.1.3, "Factors of Demand") is the need for high-speed LAN-LAN interconnections, which is not a typical application of today's VSAT systems. BISDN rates will be in excess of 50 Mb/s, which also exceeds the capabilities of today's VSAT systems.

From this analysis, it is clear that satellite has a very small potential in delivery of frame relay and SMDS traffic. However, BISDN is a potentially significant market, especially after 2001 when BISDN-capable satellites are likely to be available.

FIGURE 5-3
Satellite-Addressable Frame Relay Traffic

DSOs	% Satellite Addressable	Busy Hour DSOs 1991	1996	2001	2006	2011
Data						
Facsimile	1%	31	1300	180	22	14.5
E-Mail	1%	0	2.1	58	140	150
Terminal Operations	1%	0.82	30	36	26	19.0
On-Line Info. Services	-	-	-	-	-	-
EFT	1%	0.190	12.0	10.0	5.9	3.1
EDI	1%	0.060	2.8	2.8	1.60	0.83
Total DSOs		32	1,350	290	195	190
Total Traffic Value ($ 000)		$200	$8,300	$1,800	$1,200	$1,150

Source: Booz·Allen analysis

FIGURE 5-4
Satellite-Addressable SMDS Traffic

DSOs	% Satellite Addressable	Busy Hour DSOs 1991	1996	2001	2006	2011
Data						
Facsimile	1%	-	160	230	110	73
E-Mail	1%	-	0.26	73	700	750
Terminal Operations	1%	-	3.7	45	130	95
On-Line Info. Services	1%	-	-	-	-	-
EFT	1%	-	-	-	-	-
EDI	1%	-	0.35	3.5	8.0	4.1
Total DSOs		-	165	350	950	920
Total Traffic Value ($ 000)		-	$1,000	$2,200	$5,900	$5,700

Source: Booz·Allen analysis

5.2 VSATS

Section 4 distinguishes star and mesh VSATS principally on the basis of the communication requirements: star configurations' remote sites communicate mostly with the hub, and remote-remote connections are rare; whereas mesh configurations require remote-remote connections. This section discusses the potential markets for both mesh and star VSAT systems. Many, but not all, VSAT applications could be carried on the terrestrial PSN; therefore, VSAT is considered a "bypass" technology. For these applications, VSAT systems have proved to be an effective competitor.

FIGURE 5-5
Satellite-Addressable BISDN Traffic

DSOs	% Satellite Addressable	Busy Hour DSOs				
		1991	1996	2001	2006	2011
Voice						
MTS (Business)	1%	-	-	1,450	11,000	32,000
MTS (Residential)	1%	-	-	110	800	2,400
Private Lines	1%	-	-	1,050	4,300	7,000
800	1%	-	-	360	2,400	6,500
900	1%	-	-	8.0	50	125
Private Networks	1%	-	-	65	650	1,900
Data						
Facsimile	1%	-	-	45	55	145
E-Mail	1%	-	-	14.5	350	1,500
Terminal Operations	1%	-	-	9.0	65	190
On-Line Info. Services	1%	-	-	0.020	0.23	1.15
EFT	1%	-	-	2.5	14.5	31
EDI	1%	-	-	0.70	4.0	8.3
Video						
Network Broadcast	1%	-	-	7.3	36	73
Cable TV	1%	-	-	28	200	480
Education TV	1%	-	-	8.5	65	140
Business TV	1%	-	-	75	480	980
Viewer Choice TV	1%	-	-	240	2,400	11,000
Total DSOs				3,500	23,000	64,000
Total Traffic Value ($ 000)				**$22,000**	**$140,000**	**$400,000**

Source: Booz·Allen analysis

5.2.1 Technical Adequacy

Because VSATs by definition are satellite applications, the question of technical adequacy is not whether a satellite can be used for VSATs, but rather what applications VSATs are technically capable of addressing. This subject is discussed in section 4.3.1 for star and mesh VSATs in general and in section 4.3.1.2 for Spar Aerospace's products; the following only summarizes that information.

Star VSATs are best suited for very low bit rate, bursty communications, or high-speed, bulk data transfer in situations where most of the communication is between a remote and the hub and remote-to-remote communication needs are small or nonexistent. Data rates are up to T1 (1.544 Mb/s). While voice communications can be accommodated, the satellite delay for remote-to-hub communications (or for communications that are connected to the PSN at the hub) limits the acceptability of VSATs for voice to incidental use. Remote-to-remote voice communication is very difficult because of the round-trip delay of almost 1 second.

Mesh VSATs are suited for applications that require regular remote-to-remote communications. Although it is likely that bit rates less than the DS3 rate (45 Mb/s) will be common, higher rates could be accommodated with special design. Because mesh VSAT systems have higher bit rates than star systems, they can compete with terrestrial bandwidth-on-demand systems, such as BISDN, frame relay, and SMDS, for high-speed data transfer, high-resolution video conferencing, image transfer, and other applications.

The scanning spot-beam technology in NASA's ACTS program could allow very high bit rates for mesh VSAT systems, because the very high power of the spot beam can accommodate correspondingly high transmission rates.

5.2.2 Competitiveness

While present star VSAT networks compete primarily with networks of leased voice-grade lines, mesh VSAT systems will also compete for other market segments. To fully address applications for B-ISDN, including frame relay and SMDS, VSAT providers will have to develop higher bandwidth capabilities with smaller antennas than those available today. In addition to competition among service providers, competition from foreign manufacturers will increase the pressure on the dominant American hardware manufacturers to develop improved system capabilities at lower prices.

As noted above, VSAT systems, whether star or mesh, are not competitive for applications that include a large amount of voice communications because of the subjective effects of transmission delay and the low cost of switched voice service on the PSN. An exception to this would be applications that entail voice communications to sites so remote that they are not connected to the PSN terrestrially (e.g., offshore oil platforms, desert sites). A star VSAT system has been used to provide regular telephone service to remote villages in Alaska since the mid-1970's. For many of these applications, VSATs will probably be less attractive than the forthcoming mobile satellite services provided by low- or medium-earth orbit satellites with their much smaller transmission delay.

All communication that exists within a closed user community can be provided by VSAT systems. Any data traffic outside such a community is not addressable. A good example is fax traffic. A minority of fax transmission takes place between departments of an organization; most fax traffic is between organizations or between organizations and the general public, requiring it to be carried through the PSN. Also, as fax machines become increasingly popular for home use, fax traffic will eventually mimic the usage characteristics of voice traffic in our society (Kratochvil May 1991). In either case, the traffic is outside a closed user community and therefore is not a major addressable market for VSAT.

All other data traffic, as it exists in a strictly closed user community, is addressable by VSAT, at least up to the 45 Mb/s level. VSAT is highly competitive with terrestrial leased line and virtual private network services not only from a cost standpoint but also in speed of deployment. Whereas leased lines may take several months to install for large systems, a VSAT system can be procured and installed in a matter of weeks.

5.2.3 User Acceptance

User acceptance of star-configured VSATs has been demonstrated by the rapid growth in the market that occurred during the 1980's and that is continuing into the 1990's. The most advantageous feature of VSAT technology is its ability to provide communications to any geographical location. Because terrestrial transmission paths are not always conveniently available, VSATs are an excellent solution for users who require quick and reliable access to geographically remote locations. Therefore, VSAT is an ideal solution for widely dispersed, closed user communities. Note that a "closed user community" is not restricted to a single corporation. It could consist of a group of entities that have sufficient need to communicate among themselves that they put up a system together. One example is Chrysler Corporation communicating with its dealers, all of whom represent distinct business entities.

Another advantage of VSAT is that the transmission path is not dedicated. Users with noncontinuous or intermittent traffic can access a satellite transponder for moments or hours and pay only for the time used. High-volume users who need to transmit information for extended periods are able to lease required transponder space for a fraction of the day. Usage-sensitive pricing of satellite transponders gives VSATs a strong cost advantage over terrestrial leased lines.

In addition to the previously discussed advantages of VSAT technology that contributed to its rapid growth, regulatory streamlining by the FCC has increased the level of user acceptance and is responsible, in part, for the rapid growth in VSAT installations. However, the restrictions placed by local communities on the outdoor mounting of VSAT antenna dishes reduce user acceptance of VSATs. Some communities consider earth stations to be unattractive, and they require zoning approvals before installation. Indoor mounting of smaller VSATs can circumvent this problem. The reduced antenna size needed for indoor mounting is possible with mesh VSAT and is a favorable factor in generating widespread user acceptance.

Although voice transmission quality is generally unacceptable for star-configured VSATs, the technical considerations of data communications are transparent to the network user. In fact, VSATs typically offer faster response times than terrestrial networks. VSAT technology is highly developed and has been proven reliable.

VSAT systems are also capable of serving the integrated video and video collection and distribution market. The high bandwidth capability of VSATs and the usage-sensitive cost structure contribute to the overall utility of video services provided by this medium. Moreover, mesh VSAT will facilitate direct video communications between any two remote locations with improved quality over star networks.

5.2.4 Traffic Estimates

Figure 5-6 presents other potential markets and the portion of total telecommunication traffic that VSAT systems can address. The results of this study indicate that VSATs will carry predominantly data traffic. VSAT applications to video will increase as video conferencing becomes more popular.

VSAT traffic is by definition 100 percent satellite addressable; therefore, traffic estimates of volume are repeated here from those presented in section 4 and estimates of value are placed on the total DS0s using the price of a fractional T1 as a proxy.

FIGURE 5-6
Satellite-Addressable VSAT Traffic

DSOs	% Satellite Addressable	Busy Hour DSOs 1991	1996	2001	2006	2011
Data						
Facsimile	100%	62,000	130,000	36,000	8,800	11,500
E-Mail	100%	0	400	19,000	74,000	120,000
Terminal Operations	100%	3,300	5900	14,500	21,000	30,000
On-Line Info. Services	0%	-	-	-	-	-
EFT	100%	100	300	500	590	610
EDI	100%	145	350	700	800	830
Video						
Network Broadcast	0%	-	-	-	-	-
Cable TV	0%	-	-	-	-	-
Education TV	100%	-	730	4,300	8,300	14,000
Business TV	100%	440,000	155,000	105,000	105,000	78,000
Viewer Choice TV	0%	-	-	-	-	-
Total DSOs		510,000	290,000	180,000	220,000	250,000
Total Traffic Value ($ 000)		**$3,200,000**	**$1,800,000**	**$1,100,000**	**$1,350,000**	**$1,550,000**

Booz·Allen analysis

5.3 INTEGRATED VIDEO

Integrated video is a term used to describe a collection of end-user video services that combine voice, and sometimes data, with still or motion video. Because integrated video is a traffic type rather than a means of telecommunication, integrated video services can be provided by VSATs and BISDN as well as by terrestrial systems. BISDN can meet the high bandwidth integrated video applications, while VSATs can meet the low-bandwidth applications, with an area of overlap in the 1.5 to 45 Mb/s range.

VSAT systems will be attractive to users who need to transmit only still video images or who require narrowband video conferences. For instance, many hospitals do not have the staff expertise to diagnose certain maladies. Often this expertise may be available only at a larger, regional hospital. For certain time-critical cases, hospitals may use VSAT communications links for quick delivery of very high resolution patient diagnostic images, such as computerized axial tomography scans and magnetic resonance imaging. For this traffic, interactive communications are not required, only delivery of the file so that it may be viewed at another location. Another example is the transmission of high-resolution CAD/CAM images between design centers and manufacturing facilities. Again, timely delivery of the image is the pertinent communications requirement.

The satellite transmission options for integrated video have already been discussed in the contexts of BISDN and VSAT systems. The technical adequacy, competitiveness, and user acceptance issues for integrated video services were covered there.

Because the user base that is satellite addressable for integrated video is similar to that of BISDN, the same methodology is used to estimate the volume and value of satellite addressable traffic. Figure 5-7 presents estimates of integrated video addressable traffic volume and value.

Note that the number of busy-hour DSOs required for Educational TV drops dramatically from 460 in 1991 to 51 in 1996 and then rises somewhat to 140 by 2011. This phenomenon is due to the introduction of video compression. Figure 2-141 shows the assumed video traffic DS0 conversion factors. It shows educational TV requiring 960 DSOs (one transponder) in 1991; this drops to 96 by 1996 and then again somewhat by 2001. The number of video channels increases over time, but bandwidth reduction due to compression greatly outweighs the growth in number of channels.

FIGURE 5-7
Satellite-Addressable Integrated Video Traffic

DSOs	% Satellite Addressable	Busy Hour DSOs 1991	1996	2001	2006	2011
Video						
Network Broadcast	0%	-	-	-	-	-
Cable TV	0%	-	-	-	-	-
Education TV	1%	460	51	130	140	140
Business TV	1%	0	360	530	950	1150
Viewer Choice TV	0%	-	-	-	-	-
Total DSOs		460	410	660	1100	1300
Total Traffic Value ($ 000)		**$2,800**	**$2,500**	**$4,100**	**$6,800**	**$8,000**

Booz·Allen analysis

5.4 DIRECT BROADCAST SATELLITE

DBS will offer entertainment programming via direct broadcast of television and digital radio. The direct broadcast market was first capitalized on by TVRO antennas installed at households that did not have access to cable television. Because of their ability to provide service to any location, TVROs are very popular in rural areas.

Several companies are proposing DBS TV and radio systems that will provide total coverage of the continental United States. The first of these proposed systems, Hughes Direct TV, expects to be operational in late 1993.

5.4.1 Technical Adequacy

Obviously, the direct broadcast of television and radio signals is technically addressable by satellite as demonstrated by the success of the TVRO market. In addition, several countries already have national broadcasting of television signals directly to homes via satellite. Future systems for the U.S. market will provide higher signal strength than currently available from satellites and improved picture quality via HDTV resolution. The antenna size required to receive a DBS TV signal will be reduced from 3 meters for a TVRO to 18 inches, thereby allowing indoor mounting of a flat plate antenna.

DBS Radio (DBS-R) faces a different addressability situation from that of DBS TV. For DBS-R, significant technological barriers must be overcome for satellites to become feasible means of transmitting high-quality radio programming. At present, satellite transponders are not of sufficient power to enable the use of low gain, omni-directional antennas for DBS-R. Because

DBS-R is a mobile as well as a fixed service, the mobile earth terminals and satellites must be specially designed to optimize signal interleaving to reduce the effects of obstacles blocking the line-of-sight path to the satellite.

A DBS-R type of service has been under discussion in the international arena since 1971 and domestically since at least 1967. With the evolution of digital capabilities and mobile satellite communications, potential quality and availability of DBS-R services have grown well beyond original expectations. By its nature, a DBS-R satellite system can be made very flexible in terms of coverage area – from a wide broadcast area to a very restricted broadcast area. The Direct Broadcast Satellite – Radio Systems tradeoff study (Golshan 1992) indicates that DBS-R will be capable of providing various quality audio signals (AM, monophonic FM, stereophonic FM, monophonic CD, and stereophonic CD) for all radio settings (fixed, portable, and/or mobile) in a variety of environments (indoor, outdoor, rural, urban, and suburban). Other studies have shown that DBS-R systems provide an economical cost per broadcast channel-hour for wide-area coverage (Sood 1991).

DBS-R offers listeners, as well as service originators, many benefits heretofore unavailable in a broadcast medium. The most important benefit is the wide-area coverage available to provide simultaneous national, regional, or continental coverage via satellite. This type of coverage opens up opportunities for audience access to new types of programming. Particular types of programming that might be made available are educational, cultural, national, or target-audience-oriented, which may not be economically attractive to offer in any other way. Governments, as well as private, domestic, and international organizations, are beginning to realize the potential benefits of establishing a DBS-R service. Domestic and international commercial communication companies have just begun to realize the potential influence they and their broadcast customers would have by utilizing this type of service. Commercial radio broadcasting has not seen such a potential for change since the introduction of stereophonic FM broadcasting. (Hollansworth 1992)

Recent tests of DBS-R conducted by NASA and the Jet Propulsion Laboratory demonstrated the technical issues involved in receiving a reasonable quality signal using available technology. The results were significant interruption of signals when the receiver passed behind obstacles such as trees and buildings. Until greater signal strength is available from a satellite, DBS-R will not meet this technical adequacy criterion for overall addressability. Yet, the several applications for DBS-R service pending with the FCC indicate that investors are confident that satellites can be deployed that will provide a signal of sufficient strength and receivers designed with sufficient sensitivity to allow use of standard omni-directional antennas. NASA and the Jet Propulsion Laboratory are developing DBS-R receivers and antennas that can provide the quality level expected by consumers.

5.4.2 Competitiveness

The competitiveness of DBS depends on the present market structure and the competitive strategies of market participants. DBS TV will compete directly with terrestrial television broadcasters and cable television operators and will compete indirectly with video rental and movie theaters. Eventually, DBS will also face competition from programming offered by VOD services.

The competitive situation is slightly different for DBS-R. DBS-R competes with AM and FM radio stations, which operate in a localized market. These stations carry little franchised programming other than music and news. More than 60 percent of radio stations use some sort of syndicated programming. In broadcasting, revenues come solely from advertising sales to local, regional, or national advertisers. The recent trend in revenues is toward more local and regional advertising and less national.[2]

Barriers to entry. Barriers to entry are very high in the broadcasting industry. Because the frequencies used for television and FM broadcasting are high enough to allow only line-of-sight propagation, all TV and FM stations are essentially local, with reception becoming very poor beyond about 60 miles. Because only 12 VHF TV channels are allocated and interference considerations dictate a large geographic spacing between stations on the same frequency and no use of adjacent frequencies in the same area, the number of possible VHF licenses is severely limited in any area. The much larger numbers of UHF channels have inferior fringe-area reception and are less desirable. CATV operators are franchised by local governments and are effectively monopolies.

In addition to geographic restriction of operations, the FCC restricts TV and radio station ownership through its 12-12-12 rule. This rule states that a single entity can own no more than 12 AM radio, 12 FM radio, and 12 TV stations. Furthermore, no entity can own more than one FM and one AM station in any given market.[3] This is a primary reason why ownership in the radio and TV industry is not concentrated. In fact, with more than 9,000 commercial radio stations in the United States, there are more than 2,000 direct owners of radio stations (Leibowitz and Buono 1989). Moreover, the FCC prohibits foreign citizens from owning more than 20 percent of any U.S. broadcast station.

Bargaining power of suppliers. The video entertainment industry exhibits some vertical integration. The four commercial television networks distribute programming exclusively to their local station affiliates, only a small percentage of which are owned by the networks. There is very little cross-involvement between the broadcasting networks and cable television networks or systems. Although Time Warner owns Home Box Office, other cable networks, and Warner Bros. studios, in general there is no overlap between the producers of entertainment programs and the distributors. Cable networks and, to some extent, major MSOs (owners of multiple cable systems) have been increasing their investment in program production, but this is still a minor factor.

In addition to networks' limiting their program distribution to affiliates, other exclusive dealing arrangements are common. In some cases, cable networks have declined to deal with alternative distribution channels, insisting on dealing exclusively with cable systems (U.S. Dept. of Commerce October 1991). As another example, premium CATV networks, such as HBO, typically have a period of time after they acquire the rights to recent movies before those movies are released on videocassette.

Generally, there are more distribution channels of video entertainment than there is supply available. This does not give program suppliers a free hand in pricing; producers of first-run television programming recover only part of their cost from the networks, with the remainder of the cost recovery plus profit having to come from overseas sales and syndication, if enough episodes are aired in the first place.

Bargaining power of customers. There are two types of customers in this business: listeners/viewers and advertisers. Advertising on CATV and broadcasting networks and stations is sold by demographic cross-section. For a given cross-section, time is bought primarily on the basis of price. DBS will undoubtedly have the same pattern. However, listeners/viewers have almost no switching costs in broadcast television and radio because the services are essentially

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[2] Section 6 discusses the industry structure of video entertainment and radio broadcasting in detail.

[3] A relaxation of its ownership restrictions placed on the industry by this rule and the 12-12-12 rule is under consideration by the FCC.

free. For CATV, viewers are essentially price takers due to the lack of a direct competitive alternative. Assuming an unregulated DBS market, the introduction of DBS TV service will increase the ability of consumers to affect pricing of all pay television services. DBS-R, however, will face a very difficult position because the direct alternative to DBS-R—AM and FM radio—is free to the listener. Because most metropolitan areas already offer a variety of programming, DBS-R will have the challenge of defining new, possibly small, niche markets or competing on other bases.

Profitability and future growth. The entertainment industry is experiencing continued growth, albeit at lower levels than in recent years. Cable revenues rose by 14.5 percent during 1990 and are estimated to have increased 13.6 percent in 1991 (U.S. Dept. of Commerce 1991; Gerlin 29 June 1992). Much of this growth was due to high growth in advertising revenues (25.8 percent), which included a 28 percent increase in local advertising. The cable industry's total revenue from subscription fees and advertising grew from approximately $17.29 billion in 1989 to $19.79 billion in 1990. Revenue from the standard cable package of basic channels was about 16 percent higher in 1990, while overall fees from premium pay cable services such as HBO and Showtime expanded by a more modest 5.2 percent (U.S. Dept. of Commerce). Although the penetration of cable use may be reaching a plateau, this high level of growth in revenues indicates that cable is still very profitable and that there may be room in the market for other participants.

In July 1991, the General Accounting Office surveyed 1,505 cable systems. Results indicated that the price of the most basic cable service rose by about 9 percent from December 1989 to April 1991. Yet, the average subscriber's total bill rose only 4.2 percent during the same period. A factor explaining this seeming contradiction is that many consumers are finding that premium channels are a luxury item. Consequently, consumers are dropping the higher priced premium channels, which carry greater programming costs, to lower their total bill. This conclusion is supported by the comparatively small rise in pay channel revenue in 1990.

Total revenue for the CATV industry should expand by 10.5 percent in 1992, even though new subscription fees will be limited in view of the already high level of household penetration. This growth will be led by increases in advertising revenues, especially in the emerging local advertising segment. The established pattern of relatively few subscription cancellations after installation will continue to buoy industry profitability. Experts estimate that annual increases in cable industry revenues will not exceed 7 to 10 percent through 1995 (U.S. Dept. of Commerce). This tapering off of revenue growth from the double-digit growth rates experienced throughout the 1980's indicates that cable television may be entering the mature stage of the product life cycle. U.S. cable penetration is expected to reach saturation at 70 percent of the nation's households by the year 2000.

Radio broadcasting advertising grew 4 percent in 1991 and is expected to increase by 6.4 percent annually over the next 5 years. Television advertising revenue growth was flat at 2.4 percent in 1991 but is expected to increase to 6.3 percent annually in the next 5 years (Gerlin).

Cable's ability to generate revenues from both advertising and subscription fees provides the industry with a strong competitive advantage over broadcast TV networks. Although broadcast networks remain the prime advertising vehicle for reaching a mass audience, cable has eroded much of this viewership. More than 61 percent of all U.S. households now subscribe to basic cable, compared to 23 percent in 1980. The growth of CATV, coupled with that of the home video industry, has been pivotal to the shrinkage of the major networks' national prime-time audience, from 93 percent in 1975 to 64 percent in 1990 (U.S. Dept. of Commerce).

To summarize, DBS ventures face significant competition in the delivery of video entertainment, especially in urban areas. Although the most direct competition is from CATV (including TVRO) and local broadcasters, video rental outlets and movie theaters also compete for the consumer's video entertainment purchases. The barriers to entry are very significant due to the fragmented but near-monopoly standing of local cable operators. The market for CATV entertainment is entering the mature phase of the product life cycle in terms of penetration of service, but the relatively high growth in revenues indicates that room exists for other participants. A market opportunity exists for DBS TV in the approximately 30 million homes that are not passed by CATV systems in sparsely populated regions. In that market segment, TVRO is the dominant distribution medium, but DBS can offer a cost advantage in customer premises equipment.

5.4.3 User Acceptance

Varying grades of products are possible with DBS. With DBS TV, a standard NTSC image can be received with very good quality compared to terrestrial broadcasts. Clarity of reception is one advantage that cable exploits. In addition to a standard image, high definition images (i.e., HDTV) can be broadcast in an efficient manner by using satellite. The projected availability of HDTV broadcasting in the very near future is a strong competitive advantage for DBS TV. Terrestrial broadcasters must invest millions of dollars per station to be capable of HDTV broadcasting, whereas DBS can immediately provide HDTV signals. Consequently, many terrestrial broadcasters may not be able to upgrade their facilities for several years. DBS's ability to spread the initial fixed cost of the satellite across the entire United States, or at least a complete time zone, will allow low-cost service to the consumer.

Most cable systems are limited to approximately 50 channels of programming because of the bandwidth of the coaxial cable. But the higher bandwidth required of HDTV programming will drastically reduce the total number of channels that a coaxial-based system could provide. Cable TV companies will need to invest heavily in upgrading their cable plants with HDTV to maintain the present level of diversity in their channel offerings.

DBS-R systems can more easily reduce the bandwidth required to broadcast a channel by providing varying grades of audio quality for certain appropriate formats such as news/talk radio. Based on the status of audio coding technology, several grades of audio quality and bit rates are possible. The table below shows the bit rates and comparable quality of different DBS audio qualities (Golsham October 1991).

Audio Quality	*Bit Rate Required*
Digital broadcasting of AM audio	16-32 kb/s
Digital broadcasting of monophonic FM audio	48-64 kb/s
Digital broadcasting of stereophonic FM audio	96-128 kb/s
Digital broadcasting of monophonic CD audio	128-160 kb/s[4]
Digital broadcasting of stereophonic CD audio	192-256 kb/s

Because Direct Broadcast Services are consumer-oriented products, the viability of the market is heavily dependent on widespread user acceptance. As discussed in detail in section 6, two major factors influence the purchase decision of consumers: price and convenience. For the consumer, the prices of consumer premises equipment, fixed monthly charges, and usage-sensitive costs are major decision factors in choosing how much programming to purchase or whether to purchase programming at all. Convenience factors such as home delivery, user-defined

[4]New range recently achieved with data compression techniques by AT&T Bell Laboratories, Murray Hill, NJ and other research laboratory locations.

scheduling, pause and replay, and variety of selection are also important decision criteria for the consumer's purchase of video entertainment.

DBS is a natural outgrowth of TVRO. TVRO provides virtually equivalent services at very competitive prices. Rental of the receiving dishes is typically included in the monthly service fee. The installed base of 3 million subscribers with an estimated annual growth of more than 300,000 new subscribers per year demonstrates the widespread acceptance of TVRO in less densely populated areas. DBS can address the approximately 30 million homes without access to cable television by providing a higher quality alternative to terrestrial broadcasting. But as cable TV service prices continue to rise, DBS-TV can also become a potential competitor to cable in urban areas. A major restriction to DBS-TV's acceptance in urban areas is the outdoor mounting of antenna dishes. Some communities restrict the use of outdoor antenna dishes for aesthetic reasons. Development of smaller antennas that could be mounted indoors is crucial to successful penetration of DBS-TV in urban areas.

However, DBS-TV may not achieve penetration rates in this market segment equivalent to what cable has experienced in its market. The main reason is that a rural population typically has less discretionary income with which to purchase programming than does an urban population. In addition, revenues from advertising will probably be lower than experienced by other, more mature, national media because of the relatively fewer numbers of households and the relatively lower levels of retail sales. These two factors influence the purchase decision of advertisers for broadcast TV and radio and will be important to any advertising-dependent DBS venture. These same factors are also important considerations for DBS-R ventures.

Switching costs will be important determinants of user acceptance for both DBS TV and DBS-R. Initially, the products will be considered a "luxury" because of their novelty and, therefore, will likely demand higher prices than other forms of entertainment programming. DBS-TV operators will face less of an obstacle in gaining viewers, because the commonality of cable TV has desensitized the TV consumer to paying for in-home programming. Moreover, to receive HDTV programming, the consumer will be required to purchase a new television set regardless of whether the delivery system is terrestrial or satellite broadcasting. This will make DBS TV more of an incremental cost to the consumer who wants HDTV-quality programming. DBS-R users will also be required to purchase special equipment to gain access to the broadcasts and may resist the purchase of programming that they have received free in the past.

Initially, DBS-R consumers will fit a narrow market niche. These will be individuals who spend a significant portion of their day near a radio, such as outside salespeople and truck drivers. DBS-R may also have a market for vacationers who travel to remote locations and are, therefore; outside their usual listening area. Mobile audiophiles who desire high-quality music programming will be the other end of the user scale.

5.4.4 Traffic Estimates

Traffic volume and value for DBS cannot be estimated with confidence because of the limited data available. Section 6 examines the issue of DBS business viability, which is independent of channel demand.

5.5 MOBILE SATELLITE SERVICES

Although MSS can deliver other telecommunications services, such as RDSS and paging, it is primarily intended to offer mobile voice and data communications to areas not presently covered

covered by mobile communications services. Video is not presently feasible via MSS[5] because its high bandwidth requirement exceeds that which an MSS channel can provide.

5.5.1 Technical Adequacy

MSS is by definition technically addressable by satellite. Although the technology does not already have a sizable installed base, some of the technology being employed has been investigated heavily by NASA and the U.S. Department of Defense (DoD). Moreover, since its creation, INMARSAT has offered mobile communications to the maritime industry. The earliest venture in MSS, AMSC, plans to begin offering its full MSS service in mid-1994. It has already contracted for construction of its first satellite and launch vehicle. Another widely publicized MSS venture, Motorola's Iridium, is proposed to begin operation by 1995. In addition to these two major systems, several other proposals have been submitted to the FCC by companies for low-earth-orbit, medium-earth-orbit, and ellipitical-orbit systems.

5.5.2 Competitiveness

The market for MSS, as explained in section 4, is the provision of mobile data, voice, paging, and geographic location services. However, these services are already being provided in most metropolitan areas, often at much lower costs to the user than are proposed by most MSS systems. Therefore, MSS will not be able to compete effectively for subscribers in these areas. Instead, MSS will find a significant customer base with those users not covered by terrestrial services. Users residing in or traveling to geographically remote areas or areas inadequately served by terrestrial means will be the prime source of revenue for these systems. The former is the potential market for MSS in the United States and other economically advanced countries, and the latter is the potential market for MSS in developing countries.

Barriers to entry. As with almost all large-scale telecommunications ventures, the barriers to entry are very high. For instance, regulatory approval must be granted by the FCC for operation in the United States and by many other countries for global systems. Because unused frequency spectrum is increasingly scarce, often only a limited number of licenses are granted for any particular geographic region. Constraints in frequency availability compounded by the limited supply of geosynchronous orbital locations have created very significant hurdles for MSS to overcome. This was part of the reason for the FCC's mandating that a consortium be formed for the first MSS license among the several applicants.

The second hurdle is the very large capital investment required to enter the market. Motorola, for instance, will require more than $3 billion to launch its entire planned system. The nearest direct competitor of MSS—terrestrial cellular networks—is a similarly capital-intensive business. The large investment required tends to reduce the effect of the first hurdle, regulatory controls, because few competitors are capable of making the sizable investment to build and operate a system, thereby reducing demand for licenses from less financially-capable companies.

Bargaining power of customers. The direct alternative to MSS voice in urban areas is the existing, strongly established, cellular operators. For urban users, switching costs are significant because most operators subsidize the price of user equipment. Consequently, for MSS to penetrate the urban market, not only will the service cost have to be competitively priced on a per-minute basis, but MSS user equipment will need to be heavily subsidized as an inducement for users to choose MSS over terrestrial cellular. The cost for MSS to operate in urban areas is so high that most MSS operators will not find it a viable market for their businesses.[6]

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[5] With the exception of INMARSAT's 56 kb/s high-speed data service.

[6] MSS would also face competition in the future from personal communications networks and mobile voice offered by SMR operators.

However, MSS will be able to provide voice competitively to those users who frequently travel outside cellular coverage areas. For instance, in rural areas, cellular coverage reaches only a few hundred feet beyond interstate highways. Users traveling beyond the interstate who need mobile communications will find MSS useful. Another example of a potential MSS voice niche is the frequent traveler who needs communication while in flight. Currently, voice communication availability on public airlines is limited to Airfone™, and data transmission is not yet available. Not all airplanes are equipped with Airfone™ equipment, and those that do have very poor transmission quality compared to other means. Moreover, Airfone™ service costs $1.50 per minute of usage. At approximately $1 per minute, MSS can offer superior voice quality at a competitive price.

MSS will also face strong competition from terrestrial operators of wireless mobile data networks such as those available from RAM Mobile, ARDIS, and the many SMR operators. Industry expectation of substantial growth from the relatively small installed base indicates that mobile data could be a viable niche for MSS. With the roll-out of digital cellular and the resulting efficiencies in spectrum utilization and improvements in cellular modem technology, increased data speeds with low bit-error rates will provide cellular operators with a strong competitive advantage in mobile data.

RDSS can be provided very easily by MSS. However, RDSS service providers must compete directly with the Global Positioning System (GPS) that relies on a DoD satellite; the DoD does not charge for this service. The GPS will report position directly to the mobile terminal. To be commercially valuable, this information must be transmitted to a central control station, such as a truck dispatcher, where the information can be utilized to manage resources more efficiently. This will require a low-speed data messaging system capability to be built into the mobile terminal. The ability of MSS operators to package RDSS into their user equipment will result in manufacturing economies and a reduction in transponder usage from elimination of the second up and down links. Therefore, the price of MSS services could be lower than comparable GPS-based systems.

The ubiquity of terrestrial paging services and the intense competition among paging service providers have already pushed the cost of the terminal and service to very low points. For local paging service in larger metropolitan areas, several paging companies may compete, but nationwide only a few do. The rental cost for a paging terminal ranges from $7 (local only) to $17 (nationwide). Service cost can be acquired for under $10 for local service and under $60 for nationwide paging. International paging is charged on a per-page basis of approximately $1.25. MSS paging will be competitively priced only for the nationwide and international paging users. MSS can also provide this user base with increased coverage over terrestrial systems that must arrange for the actual page to be sent by a local system. Coverage of nationwide terrestrial paging is limited to metropolitan populations of 50,000 or greater. Furthermore, international paging is limited in the number of countries in which a user can receive a page.

5.5.3 User Acceptance

Voice quality will be very good with MSS because of the specially designed high-power satellite and specially designed handsets. Although some MSS systems use geosynchronous satellites, transmission delay can be tolerated because of the lack of a competitive alternative. Furthermore, companies, such as AMSC, have designed dual mode handsets that first attempt to deliver the call via the terrestrial cellular networks and then, if the call is not completed, attempt delivery via the MSS. This gives users increased utility without requiring MSS for all calls. In this example, MSS is a complement to terrestrial cellular service rather than a direct competitor.

Acceptance of MSS in providing mobile data will be limited because of the relatively low transmission speeds possible. In the mobile data market, several terrestrial options exist. Mobile radio data networks, such as Motorola/IBM's ARDIS system, can provide up to 19.2 kb/s service to most metropolitan areas. Digital cellular will be able to provide similar data rates in the near future. Most MSS systems can achieve data rates of only 4,800 b/s, limiting their use to laptop computers. Unless MSS prices for data service can be reduced below those of terrestrial providers, the lower transmission speed will be acceptable only for users who have no mobile alternative, such as those who are in remote locations or where the terrestrial infrastructure is inadequate. For instance, automatic transmission of data from unattended remote sensors is a potentially important market for MSS.

RDSS may partially overcome competition from GPS-based systems by offering greater precision of positioning. GPS is not allowed to operate in the "accurate" mode and therefore cannot determine a position to less than 300 meters, whereas non-GPS systems can determine a position to within a few meters. Because MSS offers a superior alternative to GPS, its RDSS should meet with a significant level of user acceptance.

MSS paging service will be superior to terrestrial services from the standpoint of coverage. Frequent business travelers and service personnel who are often out of the terrestrial coverage areas will have the greatest use for this type of paging service.

5.5.4 Traffic Estimates

Traffic volume and value for MSS cannot be estimated with confidence because of uncertainties regarding subscriber usage, equipment and system pricing, and competing technologies. Section 6 reexamines the issue of MSS business viability.

6.0 SATELLITE CAPTURABLE MARKETS

A telecommunications carrier can gain a competitive advantage in two basic ways: it can gain cost leadership that allows it to price its service lower than its competitors' services, or it can differentiate its services from competing services (Porter 1985, 11). Product or service differentiation can compete by precisely matching the needs of a particular market segment or by offering a desired combination of premium price and performance. This section assesses satellite's potential to achieve competitive advantage in the satellite-addressable markets identified in section 5.

6.1 VSAT

Mesh VSAT can address the need for lower data rate (less than 45 Mb/s; see section 4.3.1.3) broadband services applications. Mesh VSAT can also provide integrated video functionality. The most promising VSAT market is for private networks (i.e., closed user communities). In this market segment, lower cost is likely to be an important route to competitive advantage. The importance of cost is due to the precisely specifiable nature of users' expected performance in terms of capacity and availability. Corporate users have proven themselves willing to adopt multiple sources if performance is equivalent to their current services. Consequently, service providers using satellite technologies will be best able to capture traffic based on cost. The scale of the user community and other quantifiable variables play a major role in determining the cost-competitiveness of a satellite application.

To define data communications markets capturable by mesh VSAT, this section uses three general models to compare VSAT networks to terrestrial services based on private line and virtual private networks. The models compute a discounted life-cycle cost for each alternative under a variety of assumptions about user requirements and the future environment. Multiple solutions of this model delimit the conditions under which VSATs can capture traffic from terrestrial alternatives.

This section uses hub-and-spoke VSAT, the only currently implemented technology, to identify key relationships and trends. These trends and relationships are adapted to apply to mesh VSAT in section 6.1.2.2.

6.1.1 Models

This analysis adapts existing models to evaluate the competitive capture potential of satellite broadband services. The result is an adaptation of two models published by Sharma (February 1989, 31). The two models are used to compare the economics of VSAT services to terrestrial alternatives.

The first model derives multidrop private-line network cost from several variables. Commercial carrier tariffs comprise a substantial portion of network cost. The scale economies of a multidrop line network depend on how the cost of long-distance transmission is shared and on interuser distances.

The second model derives the cost of VSAT networks as a function of several variables. Investment in terrestrial facilities (VSATs and, where applicable, hubs) represents a substantial portion of network cost. The scale economies of a VSAT network depend on how transponder resources are shared among terrestrial facilities. In contrast to multidrop-line network cost, VSAT network cost is independent of distance.

This analysis modifies these models in several ways. In the original model, an amortization factor was associated with investment costs to include amortization and the cost of funds. This converts one-time investments to recurring costs.

This analysis separates initial and recurring costs to change the output of the model from monthly cost to discounted life-cycle cost. Discounted life-cycle cost is derived by using the timing of costs as well as their size to judge overall economic impact. The discounting procedure reflects the time value of money. Because discounted life-cycle cost is the most comprehensive measure of cost, many commercial enterprises use discounting to assess investment projects. Firms that do not use discounting usually use return-on-investment criteria, which are mathematically equivalent to discounting under certain simplifying assumptions. To place discounted system costs on a comprehensive life-cycle basis, the Sharma models are adapted to explicitly consider the maintenance cost of user-owned facilities.

As adapted, the VSAT model expresses the cost per VSAT site as follows:

1. Initial cost per VSAT = IVSAT + (IHUB * HUBS) / VSATS

2. Recurring cost per VSAT =
(IVSAT + IHUB * HUBS) * OM + (XPONDO + XPONDI * CARRIERS) / VSATS

IVSAT: Installed cost per VSAT

IHUB: Installed cost per hub (may equal 0 in a mesh VSAT system)

VSATS: Number of VSATs using the network

HUBS: Number of hubs necessary to support N VSATs
= INT [VSATs / (VSATs supported by a hub)] + 1

OM: Monthly operations and maintenance cost, as a percentage of investment in VSATs or hubs

XPONDO: Transponder cost per month for a hub-to-VSAT carrier (assumes one carrier is shared by all VSATs)

XPONDI: Transponder cost per month for a VSAT-to-hub carrier

CARRIERS: Number of hub-to-VSAT carriers necessary to support the assumed number of VSATs using the network = INT [VSATs / (Number of VSATs per hub-to-VSAT carrier)] + 1

Initial and recurring costs are used to compute annual cost in each year of the life-cycle for discounting.

The equation for the number of hubs increases the number of hubs when hubs are at full capacity, rather than increasing the number of hubs only when capacity is exceeded. This is consistent with a provisioning policy that procures equipment in advance of when it is needed, to provide spare capacity for growth or replacement. The defining equation for carriers behaves the same way.

The multidrop network model is based on commercial carriers' private-line tariff structures. As adapted, it expresses the cost per VSAT site as follows:

3. Initial cost per drop site: CONN + COORD + LLINST + MODEM

4. Recurring cost per drop site:
$(MODEM * OM_{PL}) + (MPM_{LL} * MILES_{LL} + MF_{LL}) + (MPM_{MDL} * MILES_{MDL} + MF_{MDL})$ / DROPS

CONN: Initial connection cost per central office

COORD: Initial access coordination cost per central office

LLINST: Initial installation cost per local loop

MODEM: Installed cost per modem

OM_{PL}: Monthly operations and maintenance cost, as a percentage of modem investment

MPM_{LL}: Monthly per mile cost per local loop

$MILES_{LL}$: Average length in miles of local loop

MF_{LL}: Monthly fixed cost per local loop

MPM_{MDL}: Monthly per mile cost of multidrop line (this is a step function changing between mileage bands specified in commercial carrier tariffs)

$MILES_{MDL}$: Average length in miles of multidrop line = (drops per line - 1) * (average mileage between drops)

MF_{MDL}: Monthly fixed cost per multidrop line

DROPS: Drops per line.

As with the VSAT model, initial and recurring costs are used to compute annual costs for discounting in each year of the life-cycle.

Private network services are evolving into a significant alternative for fixed user communities. This analysis also uses a third model based on tariff structures for virtual private network services. The simpler model below reflects carrier pricing for a service in which engineering decisions are made by the carrier.

5. Initial Cost = INIT

6. Recurring Cost = RECUR + USAGE * KILOP

INIT: Constant initial cost per node (may contain multiple nonrecurring components, such as for port interconnection and network control installation)

RECUR: Constant monthly recurring cost per node

USAGE: Price per kilopacket transmitted

KILOP: Average number of kilopackets transmitted per node per month.

The time horizon of this study extends to 2011. The relative cost of the three alternatives can vary widely during this period, based on the rate of technological innovation. As explained in section 3, current cost relationships favor terrestrial fiber optic transmission.

However, the structure of the interLATA telecommunications industry is oligopolistic. Standard and Poor's reports that the three-firm concentration ratio in the long-distance telecommunications industry is 95 percent. One dominant carrier, AT&T, carries the preponderance of domestic network traffic. AT&T seems to exert price leadership—other common carriers consistently set prices a few percentage points lower than AT&T's. Price leadership generally has two predictable effects: to hold prices above marginal cost and to reduce the magnitude of price fluctuations.

Another factor affecting the telecommunications market is the trend toward "price-cap" regulation. As an alternative to ongoing attempts to measure fully distributed cost, government regulators constrain AT&T's price changes over several years by a function of inflation. Prices are currently allowed to increase to accommodate changes in carriers' input costs, which are approximated by the Gross National Product Price Index. The maximum year-on-year price increase is reduced by a productivity offset that reflects increased carrier efficiency and by a Consumer Productivity Dividend (CPD) (Federal Communications Commission, 97–130). The CPD ensures that consumers share the benefits of productivity increases in the form of foregone price escalation. Price changes within the limits imposed by the cap are rewarded with less detailed FCC scrutiny. The FCC's current estimate of the combined productivity offset and CPD is approximately 3 percent. Thus, in effect, price increases are capped at 3 percent less than the rate of inflation as measured by Gross National Product Price Index.

Price leadership coupled with price cap regulation permits a simplifying assumption for long-term price changes by terrestrial interexchange carriers. This analysis begins with the assumption of a steady percentage change in terrestrial service prices over the long term, at the maximum permitted rate. The long-term inflation rate is assumed to be 4 percent, offset by 3 percent. Therefore, the baseline competitive scenario in this analysis assumes steady 1 percent annual price escalation for terrestrial services. We assume that oligopolistic price leadership will hold unless satellite can capture a substantial portion of the market. This analysis projects cost trends in satellite technologies as described in section 6.1.2.

6.1.2 Results

This section applies equations 1 and 2 to pricing structures for 1989 and 1992 and estimates the share of network traffic that can be captured based on price competition in each case. Then assumptions are modified to reflect mesh VSAT technology, and price and cost trends are used to determine when mesh VSAT becomes cost competitive with terrestrial media.

The results below indicate that the private network market can be divided into segments according to two characteristics of the private network's user community: the size of the user community and the geographic dispersion of the user community. The number of users affects VSAT cost per node because more users can share transponder or hub costs among a larger number of terminals. Geographic dispersion affects the cost of nodes in private-line networks because longer links cost more.

6.1.2.1 Recent Trends. This section computes the results of the models above with specific data: Sharma's original data for 1989 and updated 1992 data. In the paragraphs below, the 1989 cost assumptions are summarized. These assumptions are then used to identify the types of networks that satellite services can capture based on cost. The 1989 capturability results are then varied in a sensitivity analysis and translated into market shares. Finally, the procedure is repeated with 1992 data: assumptions are specified, and results are summarized and varied in a sensitivity analysis. This section concludes with a discussion of some important qualitative factors that should be considered in interpreting the results.

Assumptions: 1989. Figure 6-1 details Sharma's 1989 cost assumptions as adapted for this analysis. Figure 6-1(a) displays multidrop line costs. For multidrop lines, central office connections for each drop site result in an initial cost totaling $232. Initial connection cost is composed of an installation charge and access coordination services. Local loop installation requires another initial cost of $440. Recurring costs for each drop site's local loop are $3.58 per mile monthly, plus a $110 flat monthly rate. Each drop site also requires a modem at an installed cost of $1,500, plus Operations and Maintenance (O&M) expenses of $15 (1 percent of installed cost) per month.

The long-distance transmission component of private-line networks has two recurring cost elements. The first element is a per-mile charge that declines with increasing distance as shown in figure 6-1(a). The second is a fixed charge determined by the length of the line. This second tariff element is actually also mileage sensitive, but cost is a step function of distance. Within broad mileage bands, fixed monthly cost is insensitive to distance.

The VSAT cost function is detailed in figure 6-1(b). VSAT terminal investment is set at $10,000 (consistent with figure 4-50), with a recurring O&M expense of 1.5 percent of installed cost. A hub accommodates up to 1,000 terminals, so hub cost is coupled to the terminal population by the step function shown in equation 1. Each hub costs $500,000 installed and results in 1.5 percent per month recurring O&M expense. Carriers are the third major VSAT cost element. Both hub-to-VSAT and VSAT-to-hub carriers are assumed to cost $2,660 per month per carrier. For the purposes of this analysis, both types of carrier accommodate 1,000 VSATs, and a hub supports one carrier.

FIGURE 6-1(a)
Original Cost Assumptions (1989)—Multidrop Line Network

Cost Element (Variable Name)	Varies With	$ Per Variable Unit	Initial/ Recurring
C.O. Connection (CONN + COORD)	Drops	$232/Drop	I
Local Loop (LLINST)	Drops	$440/Drop	I
Local Loop (Mileage) (MPM_{LL})	Drops/Mile	$3.58/Drop/Mile/Month	R
Local Loop (Fixed) (MF_{LL})	Drops	$110/Month	R
Modem (MODEM)	Drops	$1500/Drop	R
Modem O&M (OM_{RL})	Drops	1% of Modem Cost/Month	R
Long-Haul Mileage (MPM_{MDL})	L.H. Lines/Mile	Miles 0-50: $2.33/Mi/Month 50-100: $1.06/Mi/Month 100-500: $ .64/Mi/Month >500: $ .32/Mi/Month	 R R R R
Long-Haul Fixed (MF_{MDL})	L.H. Lines/Mile	Miles 0-50: $ 58.74/Month 50-100: $122.24/Month 100-500: $164.24/Month >500: $324.24/Month	 R R R R L-404.6.1

Source: Sharma, February 1989

Capture potential: 1989. Figure 6-2 illustrates the effect of network dispersion and user population on satellite's potential to capture private network markets. Using Sharma's 1989 cost assumptions, figure 6-2 divides a grid into areas based on whether terrestrial or satellite technologies are more competitive. The horizontal axis of figure 6-2 is divided into intervals representing the number of user terminals in the system. Each column in the figure is labeled with a discrete evaluation point for the number of drops or terminals. The vertical axis is divided into intervals representing the number of miles between terminals. Each row is labeled with a discrete value for the number of miles between terminals. Values for the row labels are derived from the length of the multidrop line in miles ($MILES_{MDL}$ from equation 4) divided by the number of drops per multidrop line (DROPS from equation 4).

FIGURE 6-1(b)
Original Cost Assumptions (1989)—VSAT Network

Cost Element (Variable Name)	Varies With	$ Per Variable Unit	Initial Recurring
VSAT Installed Cost (IVSAT)	Terminals	$10,000	I
VSAT O&M (OMVSAT)	Terminals	1.5% of VSAT Cost/Month	R
Hub Installed Cost (IHUB)	Terminals (Step Function)	500,000/≤1000 Terminals	I
Hub O&M (DM)	Hubs	1.5% of Hub Cost/Month	R
Inbound Carrier Transponder Cost (XPOONDI)	Carrier	$2660/Month	R
Outbound Carrier Transponder Cost (XPONDO)	Carrier	$2660/Month	R

L-404.6-2

Source: Sharma, February 1989

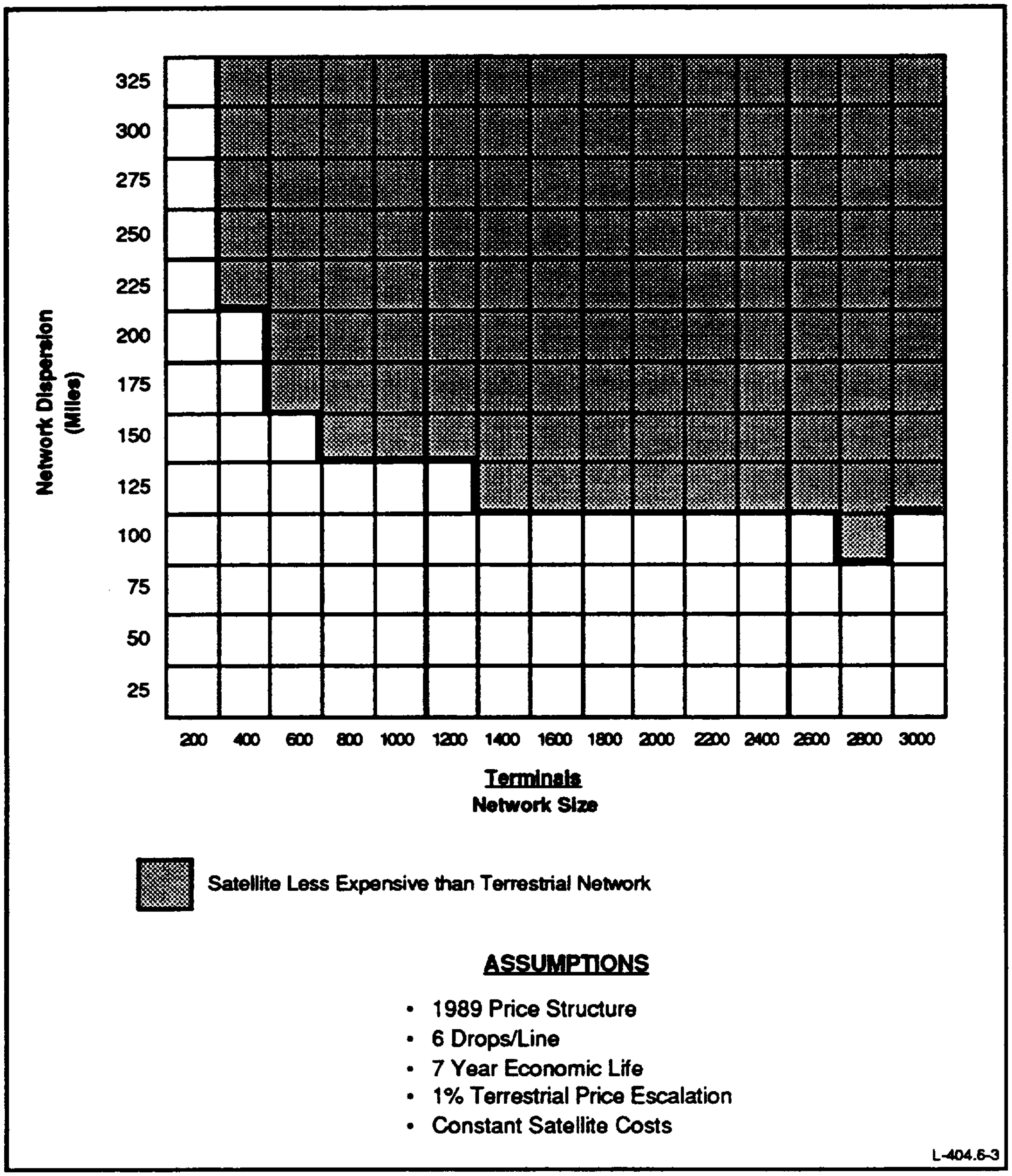
The area above and to the right of the bold line in figure 6-2 indicates the type of network that satellite can successfully compete for under the associated economic life assumptions. VSAT is most economical for larger and more geographically dispersed networks.

For systems with a 7-year economic life, VSAT is more economical with 400 terminals or more if users are located more than 225 miles apart. As the distance between users diminishes, more terminals are required before the advantages of VSAT compensate for shorter and cheaper terrestrial links. When users average 100 miles apart, VSAT is more expensive until at least 2,800 terminals are linked. The lower edge of the satellite region has a "notch." With 100 miles between users, VSAT is competitive if the network has 2,800 users, but not 3,000. This notch occurs because one element of VSAT network cost is a step function. A hub can accommodate only a fixed number of terminals—in this case, 1,000. Cost rises when the fourth hub is added, eliminating VSAT's slim cost advantage with 2,800 users.

This result is consistent with the market targeting of space communications vendors. John Chaplin of the European Space Agency pointed out that the firms perceived as most promising prospects for VSAT networks are often defined in terms of five thresholds:

- Revenues
- Number of employees
- Number of geographically separated sites
- Proportion of export sales
- Telecommunications expenditures (*Proceedings International Conf. on Satellite Comm. and Broadcasting* 1986).

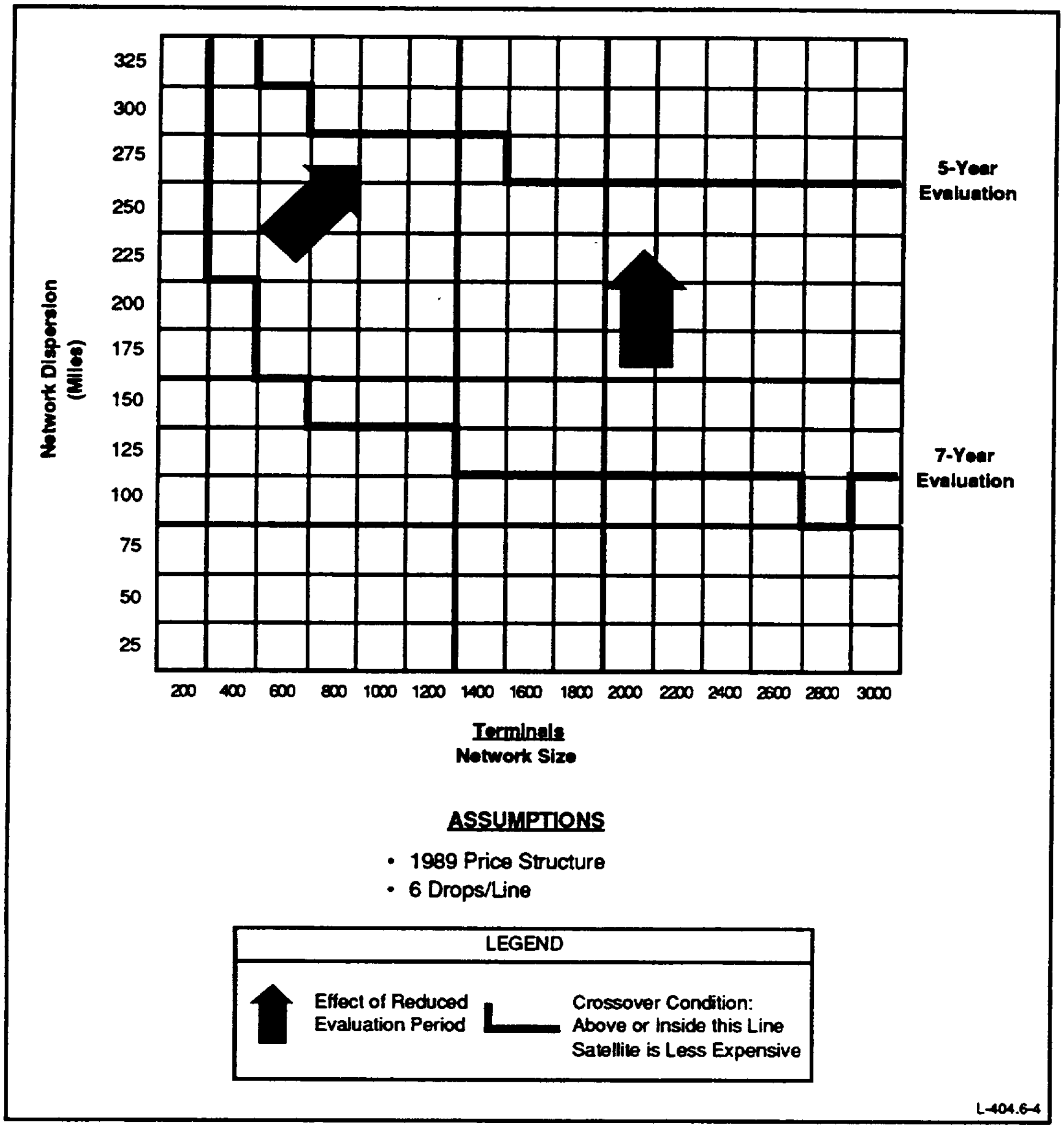
FIGURE 6-2
Satellite Capture Potential—Private Data Network



Source: Booz·Allen analysis

Firms of larger scale in terms of these measures are most likely to benefit from the strengths of satellite systems. Greater revenue and more employees imply a larger network, which reduces the individual user's shares of fixed costs. Geographically separated sites and a high proportion of export sales are indications of a dispersed firm that can benefit from distance-insensitive satellite systems. Geographically dispersed sites, particularly overseas sites, may lie beyond the crossover point at which satellite links are less expensive than distance-sensitive terrestrial links. And large telecommunications expenditures increase the potential advantage of transitioning to or investing in satellite communications.

FIGURE 6-3
Satellite Capture Potential—Private Data Networks
Effect of Evaluation Time Horizon



Source: Booz·Allen analysis

Sensitivity analysis. The following paragraphs vary the results shown in figure 6-2 to illustrate the effect of two key variables: system life and users per line. These variables are beyond the control of the satellite system operator: the former variable is a response to competitive conditions, and the latter is a technological constraint on terrestrial services.

Figure 6-3 illustrates the effect of variable system life by showing a 5-year evaluation period as well as the 7-year period that is standard for satellite systems. Evaluation of the system over a shorter 5-year period reduces VSAT's cost advantage because lower recurring costs compose a smaller proportion of total expenditures. Shortening the evaluation period to 5 years makes multidrop networks the preferred alternative until users average 275 miles apart. Salvage value is assumed to be zero.

System life may come to represent an important environmental variable affecting telecommunications technology decisions. Sharma (1989) assumes a 5-year system evaluation period, while other models are predicated on a 7-year business case. If the pace of innovation accelerates, the emergence of superior alternatives may shorten the economic life of a system. If users expect that any system fielded will be rendered obsolete by superior capabilities available in the near future, evaluation time horizons may become shorter. The resulting shorter economic life would place capital-intensive alternatives like VSAT at a disadvantage. Conversely, competition could lengthen system life by exerting cost pressure on the owners of the network equipment. Users (or turnkey service providers) might retain their equipment longer as a response to lower profits. If this longer life-cycle came to be reflected in investment decisions, satellite systems would benefit because their lower recurring costs make them more attractive when longer time horizons are considered.

The number of users per multidrop line was assumed to be 6 for the foregoing analysis. Figures 6-2 and 6-3 held private network topology constant, in the sense that the number of drops per private line was fixed. However, the number of separate user drops sharing a private line is an important factor affecting the relative cost of terrestrial and satellite networks. Network design can compensate for the distance-sensitivity of terrestrial networks by sharing each line among more users. Network operators' ability to share line cost is constrained by traffic considerations: a single line will accommodate only a limited number of drops, depending on the traffic generated by each site. However, advanced loop technologies (see section 4.2.3.3) may increase the potential number of drops per line. Figure 6-4 delimits the private networks that satellite technology can capture from networks that use private lines with varying degrees of efficiency.

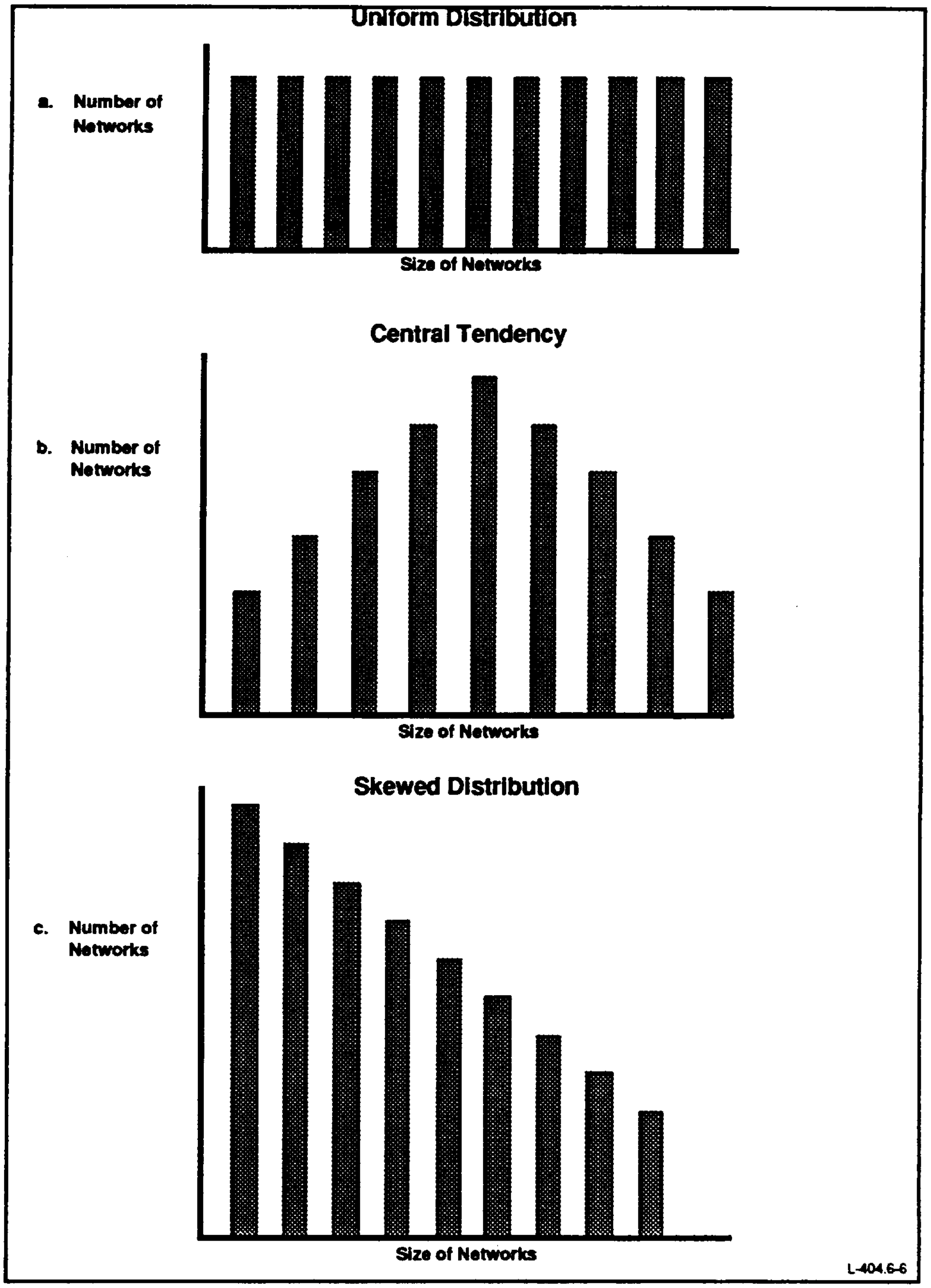
As figure 6-4 shows, doubling the number of drops per line from 6 to 12 makes more dispersed terrestrial networks competitive with VSAT. Networks with six drops per line separated by an average of 75 miles are less expensive solutions for any size network shown in figure 6-3. With 12 drops per line, drops can be separated by up to 175 miles and still be less costly for up to 3,000 users.

Translation into market shares. Figures 6-2, 6-3, and 6-4 segment markets by scale and geographic dispersion and specify satellite success in terms of market segments that can be captured. The type of networks that satellite can capture does not specify the commercial value of the business captured. To bridge the gap between segments captured and competitive viability, it is necessary to size each segment.

Only scattered information is available on the size distribution of U.S. private networks. Industry sources estimate that 27,000 private networks are in operation domestically, but most recent data are aggregated. The average and range data available do not support judgments about how many networks compose each size category.

Figure 6-5 illustrates three possible hypotheses for the size distribution of private networks. Figure 6-5(a) illustrates the case of a uniform distribution. If this pattern held, each market segment would contain a roughly equal number of networks. Figure 6-5(b) illustrates a hypothesis that network size displays a central tendency. A "typical" network exists, and most

FIGURE 6-5
Alternative Assumptions
Size of Private Network Market Segments

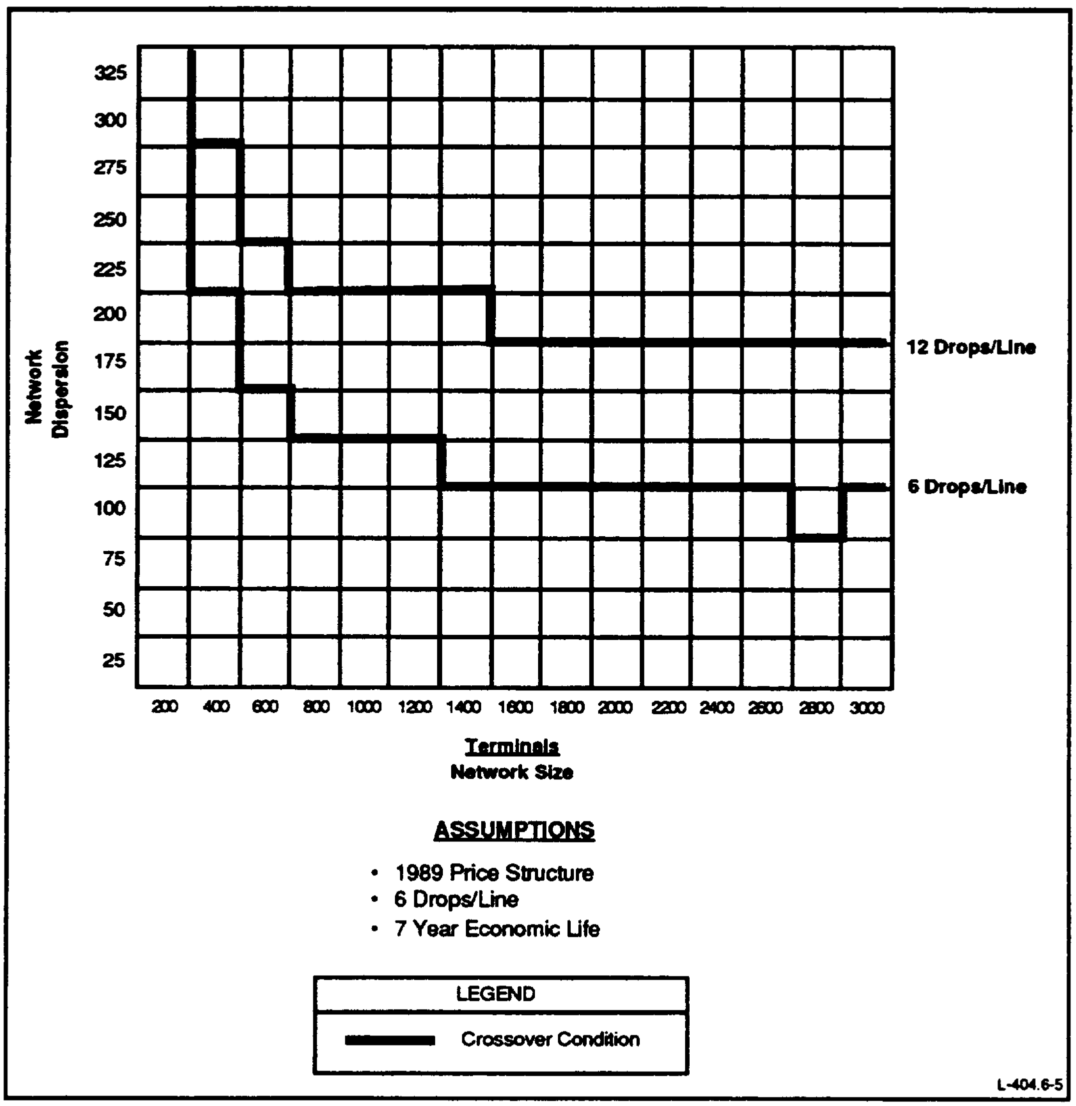


Detailed data on the facilities of some of the most effective corporate computer users indicate that user populations, as well as their networked subgroups, have a skewed size distribution. These data do not describe private telecommunications networks—they list all terminals and personal computers owned by Computer World's *Premier 100*, a list of the "most networks are similar to it in size. This might be the case if predominant technologies favored networks falling within a limited size range. Figure 6-5(c) illustrates a third possibility: that smaller networks are more numerous than larger networks throughout a broad range.

Available survey data are consistent with the third alternative. Data on corporate computer use and local area network (LAN) installations indicate a skewed size distribution. This analysis uses these data to answer the questions:

- How many network users typically need to communicate?
- Are large user communities common, compared to smaller user communities?

FIGURE 6-4
Satellite Capture Potential—Private Data Networks
Effect of Number of Drops



Source: Booz·Allen analysis

effective" computer users. This list rates users on the basis of efficiency and technological sophistication as well as computer expenditures. It is not confined to internetworked terminals. The Premier 100 could, however, be used as a working definition of the most promising market for private network suppliers. And the terminal population of these users places a ceiling on the potential size of each user community.

These data represent the size of corporate user communities with a common, if broadly defined, purpose. These user communities display a skewed distribution:

- Sixty-four percent have fewer than 20,000 computers or terminals.
- Twenty-one percent have 20,000 to 40,000 computers or terminals.
- Six percent have 40,000 to 60,000 computers or terminals.
- Eight percent have more than 60,000 terminals.

Aggregated data on the most active LAN integrators suggest that the median LAN installation, like the median corporate user population, is smaller than average (Juliussen and Juliussen 1990). For example, 63 percent of installers field networks with an average of fewer than 20 nodes. Only 21 percent of installers average 20 to 40 nodes per network. Seven percent of installers average 40 to 60 nodes. Nine percent of the installers field networks averaging more than 60 nodes. The averages obviously obscure the underlying distribution of each installer's business base. However, installers averaging fewer than 20 nodes per network installed 74 percent of the networks. Firms that install networks averaging more than 60 nodes installed only 3 percent of the networks.

The shape of the computer user population distribution is strikingly similar to that of LAN installers' average network size. Figure 6-6 compares the distribution of LAN installers with firm-wide terminal populations. It seems reasonable to assume that at every scale, smaller computer user communities are more common in private networks, just as they are in local networks and firms.

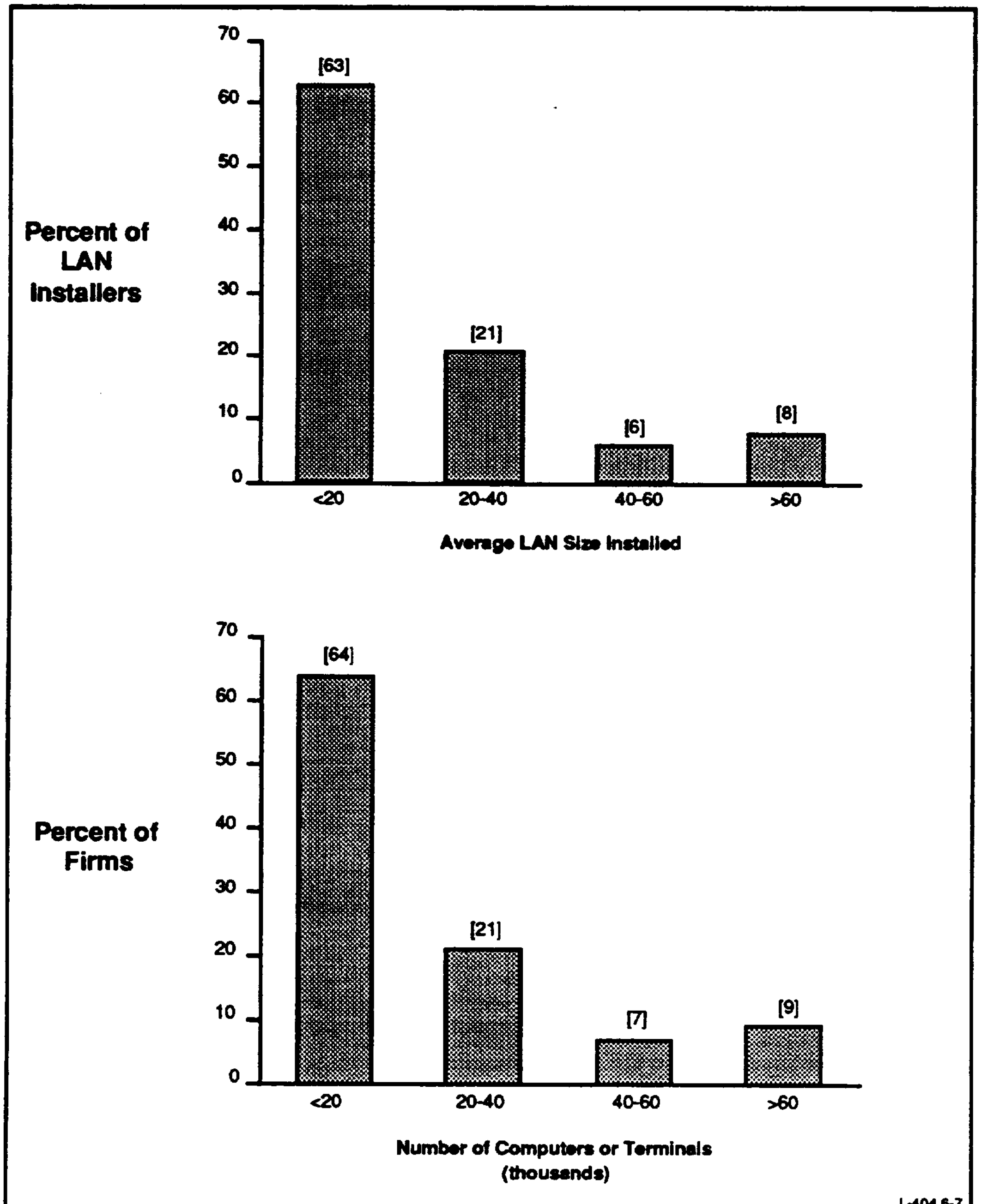
Figure 6-7 assumes a private network size distribution by analogy to figure 6-6. This network size distribution assumes a private network size range of up to 5,000 nodes. The proportion of networks declines at approximately the same rate as figure 6-6 as the size of the network doubles: 1,000 nodes is the 64th percentile, 2,000 nodes is the 85th percentile, and 3,000 nodes is the 90th percentile.

Note that figures 6-2, 6-3, and 6-4 do not display the small number of networks ranging from 3,000 to 5,000 nodes due to space limitations. Networks with more than 3,000 users constitute only 10 percent of all networks.

For business purposes, revenue is likely to be more closely associated with the number of users served than with the number of networks fielded. Figure 6-8 illustrates this point by weighting each cell in the figure by the midpoint of the size range. Figure 6-8 indicates that the preponderance of users are linked in networks with 800 to 1,600 nodes. But the larger networks that VSAT can capture provide a disproportionately large number of users. For example, we assume that only 1 percent of private networks have more than 2,800 to 3,000 nodes. However, the large networks in this segment account for 3 percent of the private network users.

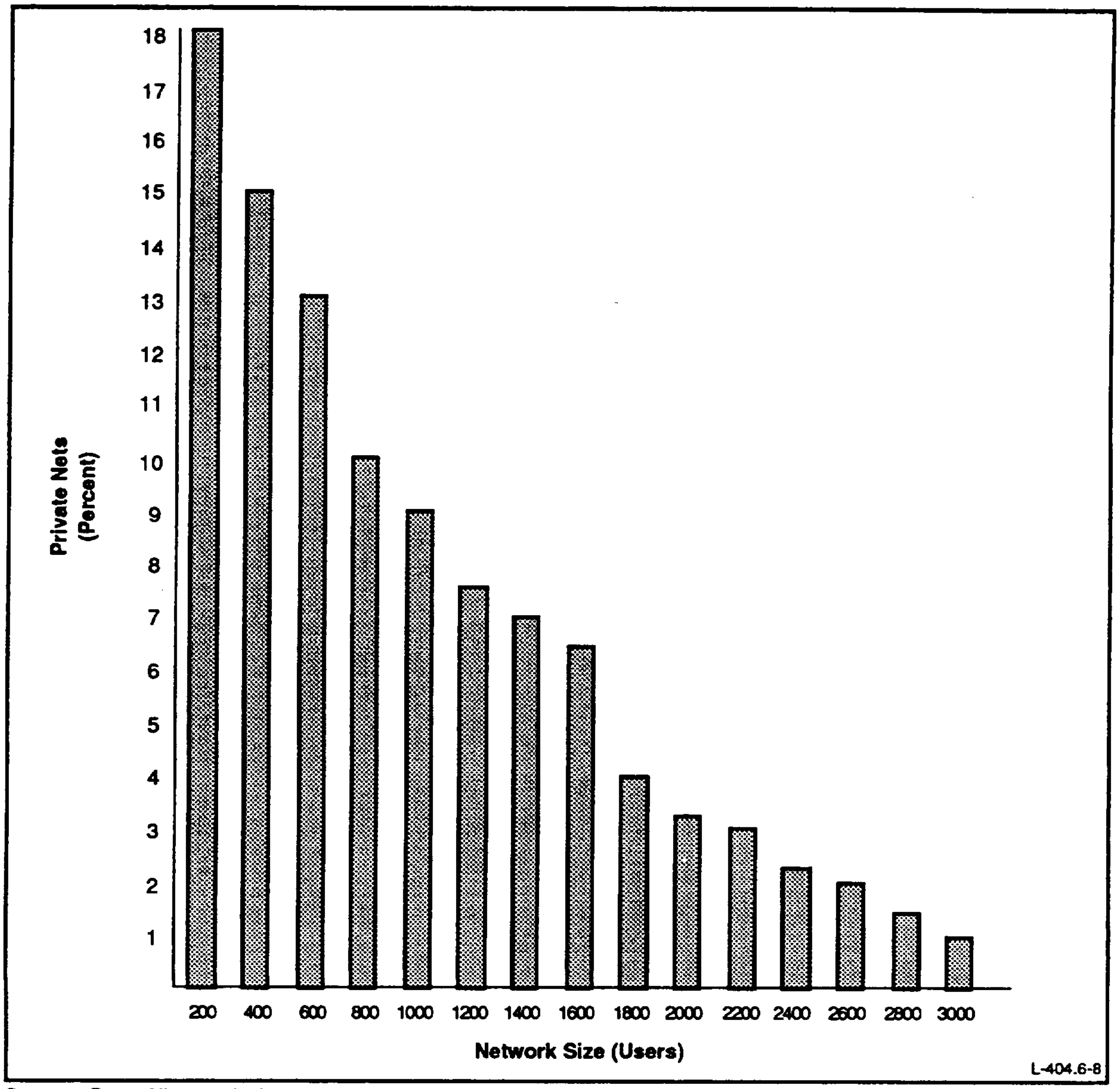
Each cell in figure 6-9 corresponds to a market segment containing networks in the size and dispersion range indicated by the row and column headings. The number in each cell represents the assumed proportion of users in the segment. Under the market share assumptions shown in figure 6-8, the 90 percent of networks with fewer than 3,000 nodes accounts for about three-quarters of network users.

FIGURE 6-6
Computer User Communities by Size



Source: Juliussen and Juliussen 1990

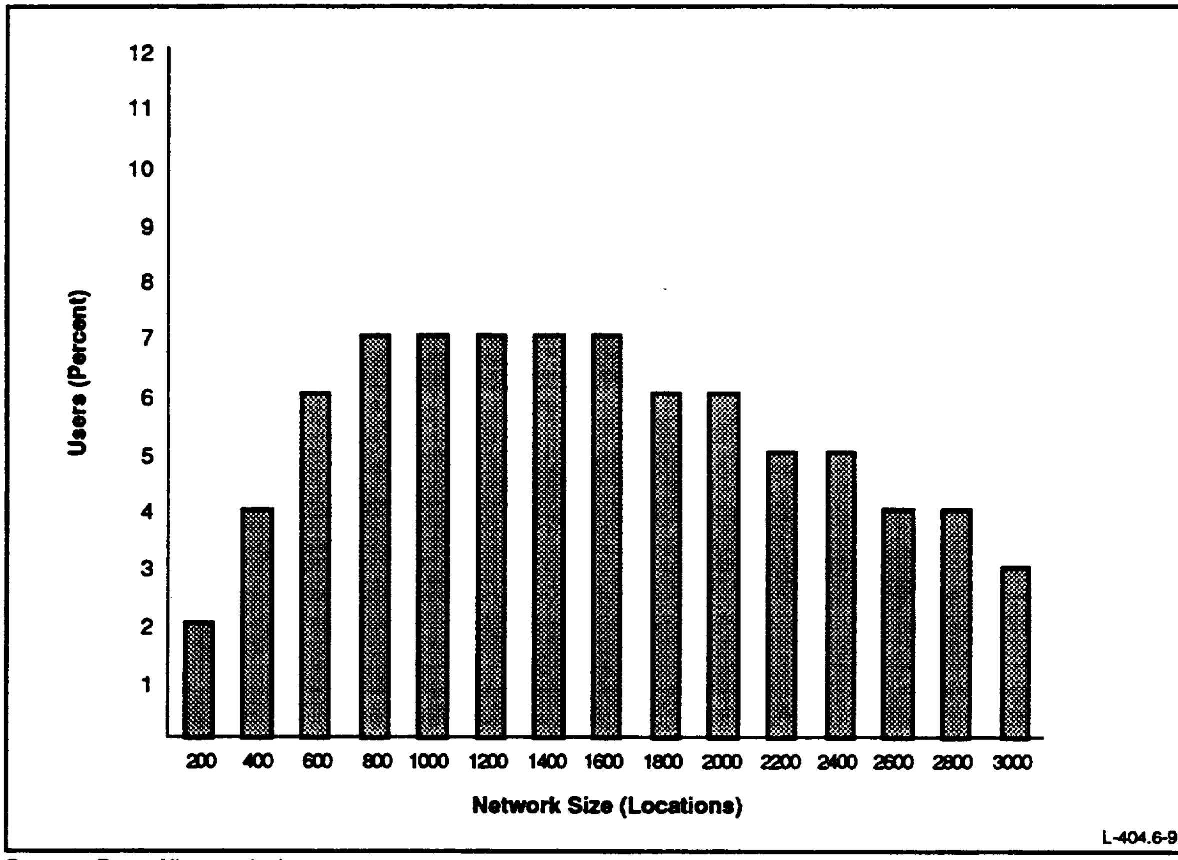
FIGURE 6-7
Network Size Distribution Assumptions—by Networks



Source: Booz·Allen analysis

In the absence of information on the distribution of network dispersion, this analysis makes the simple assumption that the average distance between nodes is uniformly distributed across networks. Under the assumption of a skewed network size distribution and uniformly distributed dispersion, figure 6-9 provides a baseline assumption for the market share included in each market segment. For example, the equal shares of .15 percent in the left column of figure 6-9 sum to the 2 (1.95) percent share in the left bar of figure 6-8.

FIGURE 6-8
Network Size Distribution Assumptions—by Users



Source: Booz·Allen analysis

Applying figure 6-9 to the capture results shown in figures 6-2 through 6-4, the following results can be summarized. With 1989 prices for VSAT networks and multidrop private lines, potential market shares are as follows:

- Forty-eight percent of users are capturable by VSAT networks competing with private-line networks averaging six drops per line, if a 7-year evaluation period is used.

- Fourteen percent of the market is capturable if prospective users compare VSAT to private networks with 6 drops per line over a 5-year period.

- Thirty percent of the market is capturable from private line networks with 12 drops per line, if users evaluate investments over a 7-year period.

The potentially capturable shares listed above are shares of the total market, but they exclude networks with more than 3,000 users, and networks with terminals separated by more than 325 miles. It is likely that VSAT can be a competitive solution for these larger and more dispersed networks.

Although the specific segment sizes are necessarily judgmental, the assumption of a skewed private network population reflects an important force operating in the telecommunications market. This market rewards "cream-skimming" by providing the greatest returns to competitors focusing on the largest users.

FIGURE 6-9
Percent Revenue Share by Market Segment

Average Miles Between Terminals	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000
325	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
300	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
275	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
250	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
225	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
200	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
175	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
150	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
125	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
100	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
75	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
50	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22
25	.15	.29	.44	.51	.51	.51	.51	.51	.44	.44	.37	.37	.29	.29	.22

Network Size (Users)

L-404.6-10

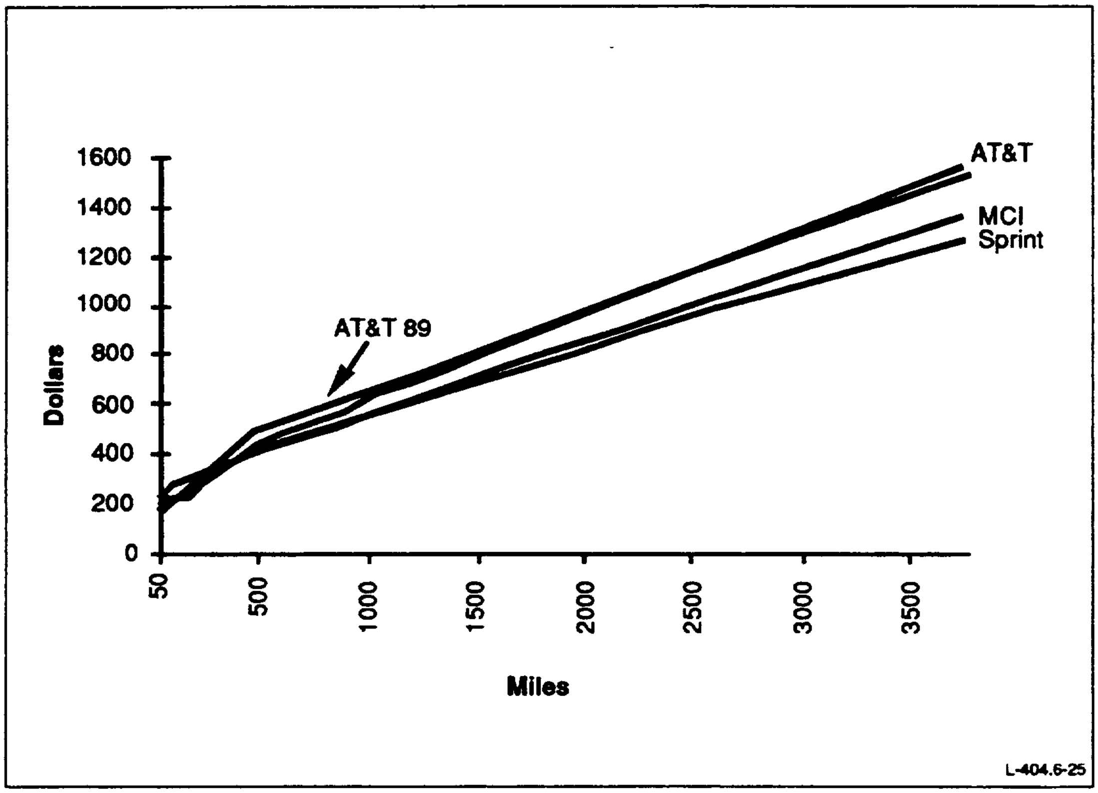
Source: Booz·Allen analysis

Potential capture does not necessarily equate to market share. Other competitive advantages determine whether VSAT reaches its competitive potential. As of 1989, terrestrial carriers had most of the noncost advantages; for example, high existing market share and entrenched customer service and sales networks. The importance of reliable telecommunications can make a telecommunications manager vulnerable to criticism if he or she diverges from the "safe choice"—an established terrestrial carrier. Terrestrial carriers have targeted business users with advertising messages that reinforce this competitive advantage by dramatizing sourcing disasters. Competitive conditions have undoubtedly slowed the diffusion of satellite innovations, resulting in market shares much lower than satellite could capture based solely on cost.

Assumptions: 1992. The next step in this analysis was to update pricing structures to 1992 and repeat the analysis. Figure 6-10 summarizes the three major long-distance carriers' published tariffs. Figure 6-10 calculates the total monthly cost (fixed charges plus per-mile charges) for AT&T, Sprint, and MCI and compares them to AT&T's 1989 prices for 64 kb/s private lines of varying length.

Figure 6-10 indicates the differences in pricing structures among terrestrial carriers. In the short-distance segment of the market, Sprint is the lowest priced carrier. From 400 to 1,500 miles, the spread between AT&T and MCI (now the lowest priced carrier) stays stable at about 11

FIGURE 6-10
Long-Distance Private Line Pricing



Source: Published tariffs

percent. Sprint begins to price more aggressively for private lines longer than 1,500 miles, and prices diverge again by up to 16 percent as distances approach 3,000 miles. Although price differentials vary, the two smaller carriers price to compete with AT&T, not with each other.

Figure 6-10 indicates that AT&T pricing has changed only slightly since 1989. Over the past 3 years, AT&T has significantly raised the prices of its shortest lines, those shorter than 350 miles. AT&T has lowered prices for longer lines, but price cuts are larger for lines of moderate length. Lines from 500 to 750 miles in length have been cut by about 10 percent, but price cuts for longer lines decline as a function of distance. The net effect is to make pricing more, rather than less, sensitive to distance.

Local connection costs appear to have changed significantly in structure since 1989. Services and pricing structures vary widely across the United States, but a systematic sample of LEC offerings provides a representative set of assumptions for 1992 pricing.

Initial cost per drop, including installation and access coordination, has declined from $672 to $417. The per-mile cost of a local channel has declined from $3.58 to $2.76, making the local office connection cheaper and less distance sensitive. Monthly fixed costs have increased slightly to $116, and they now include a minor recurring component for access coordination. Modem cost can vary widely, depending on features selected, but the median cost for a medium-speed modem is $1,250 versus the 1989 assumption of $1,500. Since 1989, VSAT costs have halved, from more than $10,000 to approximately $5,000.

Capture Potential: 1992. Under 1992 local pricing and AT&T long-distance tariffs, the cost-competitiveness of satellite improves dramatically. VSAT is cost competitive for private networks with more than 300 users, even when the distance between terminals is as low as 25 miles. When the average dispersion of the user community puts terminals an average of 50 miles apart, VSAT networks with 200 terminals are less expensive than terrestrial alternatives.

This situation permits VSAT-based technologies to compete on price with private line networks for 75 percent of the private network market. The steep drop in terminal cost combined with lower variable costs puts VSAT in a strong competitive position.

VSAT's cost structure permits us to predict with confidence that 75 percent of users would now choose satellite over other alternatives if cost were the sole consideration. Of course, cost-competitiveness is not the only factor affecting market share. Before VSAT could approach a 75 percent market share, other factors such as a competitive response by terrestrial carriers would likely constrain its penetration.

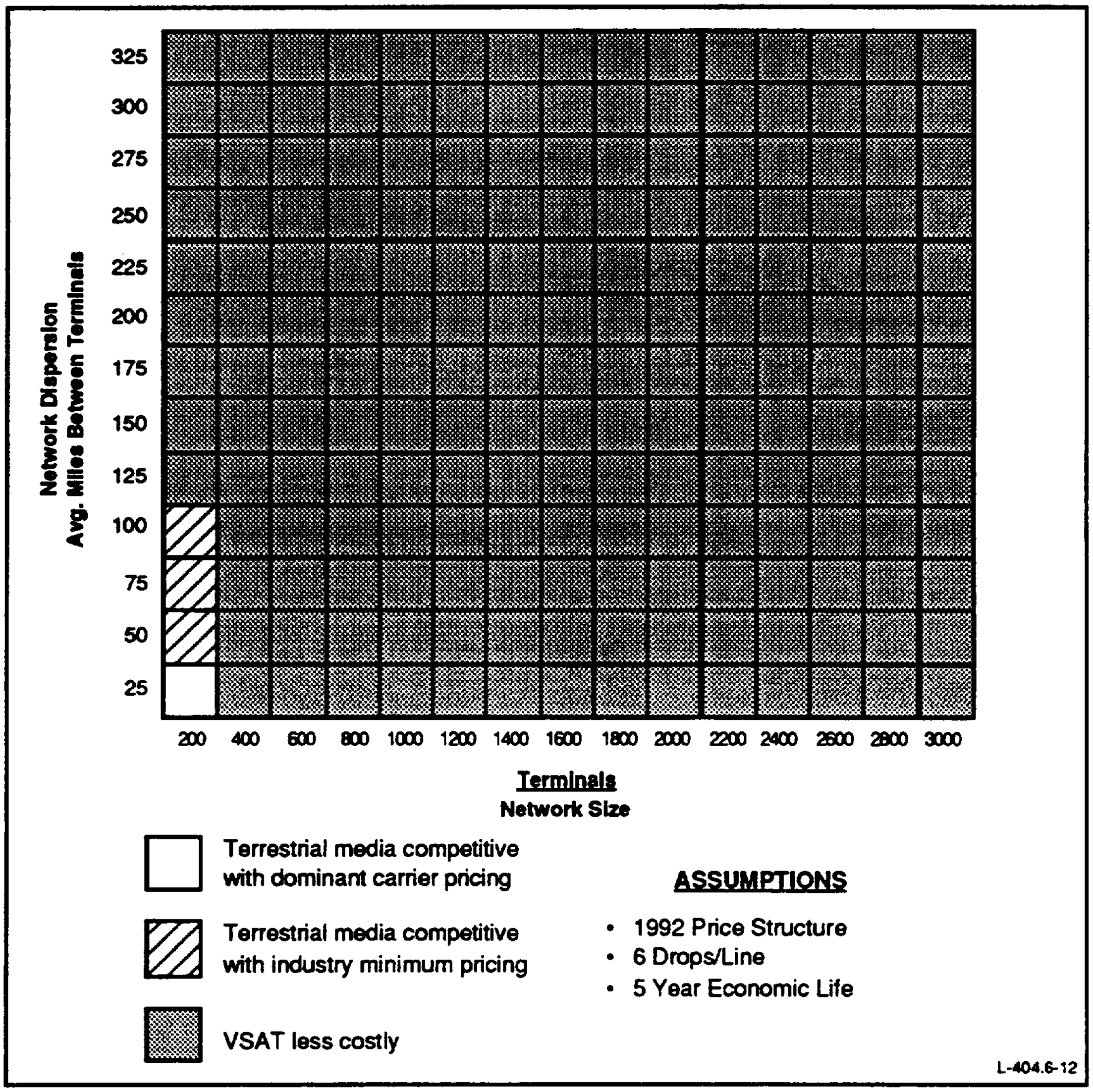
Sensitivity analysis. To gauge the effect of the terrestrial carriers' flexibility to compete on price, the rates of the lowest cost carrier can be substituted for those of AT&T. When the lowest industry rates in each mileage band are assumed, terrestrial networks are less costly for 200-node network up to the point at which terminals are separated by 125 miles. VSAT networks are still less expensive for networks with 400 users or more, whatever the dispersion of the user community. Figure 6-11 indicates the market segments where VSAT is cost competitive under AT&T and industry minimum pricing. Industry minimum pricing, however, is not a floor imposed by costs.

Discussion. From 1989 to 1992, the competitive cost position of VSAT improved markedly. This improvement is primarily due to lower earth station cost. For two reasons, however, cost-competitiveness must be qualified to constitute a complete gauge of VSAT's business potential. First, terrestrial carriers could compete more aggressively on price. Firms, at least the nondominant common carriers, would probably price more aggressively if they judged the risk of VSAT competition to be greater than the risk of disrupting the industry's relatively stable and predictable pricing policies.

The published tariffs used by terrestrial carriers create price rigidity that satellite carriers can exploit, to a point. It would be counterproductive for a major carrier to cut its tariffs for all users to recapture a small share from a competing satellite service. For this reason, price competition targeted at satellite carriers is unlikely unless satellite carriers capture a substantial share of the private network market. If satellite carriers were to capture market shares approaching those discussed above, however, terrestrial carriers would certainly make significant changes in their pricing policies.

Another reason for caution in interpreting the results above is that long-distance telecommunications firms have recently succeeded in deemphasizing price competition. Terrestrial suppliers are moving away from standard tariffs and toward customized user contracts. Satellite suppliers are deriving an increasing portion of their revenues from end-to-end network services, rather than equipment sales. The effect of these changes is to increase the importance of the carriers' ability to tailor solutions to user needs.

FIGURE 6-11
Satellite Capture Potential—Private Data Network

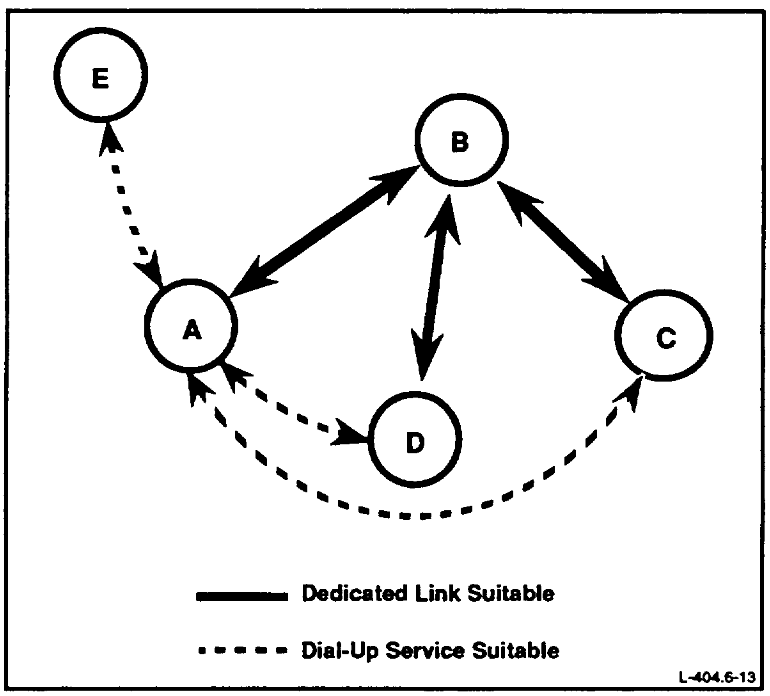


Source: Booz·Allen analysis

An example of this trend is the emergence of private network offerings that help users match their network to their communication patterns. Figure 6-12 illustrates a network with a topology that is basically star structured. Nodes A, D, and C communicate primarily with B. However, A needs to transmit small amounts of data directly on a regular basis to nodes D and C. Node A also communicates occasionally with node E.

The bold arrows in figure 6-12 indicate links suitable for private lines. The links indicated with dashed lines carry traffic patterns appropriate for services with usage-sensitive costs. The service modeled in this analysis, AT&T's Private Packet Network Service (PPNS), is more costly than dedicated lines at relatively low traffic levels. For this reason, PPNS itself does not compete with VSAT technology. However, the availability of PPNS makes a terrestrial network more adaptable to users' communication patterns than does a strictly satellite-based network. Users with a mixture of heavy and light traffic patterns would be better served by a solution combining usage-sensitive services and private lines.

FIGURE 6-12
Hybrid Network Requirements



VSAT communications suppliers must position themselves not only against private line networks, but also against hybrid dedicated and virtual networks. Satellite systems can best compete with terrestrial solutions by offering usage-sensitive services to complement their dedicated links. Accordingly, a satellite carrier could capture more networks if it served as a single point of contact integrating dedicated and dial-up transmission modes.

VSAT services offer data network users complete independence from both local and interexchange carriers. However, it would be a mistake to stress this independence to such an extent that it precludes complementary terrestrial services. The point here is that satellite telecommunications is not a distinct business. Users are indifferent to satellite and terrestrial data communications of equivalent quality and reliability. When user needs can be satisfied in different ways, excessive concentration on one transmission technology may reduce a carrier's ability to respond to the market.

Individual satellite communications suppliers may also be able to attain competitive advantage through features that are independent of whether satellite or terrestrial transmission is used. Ideally, however, satellite communications suppliers will capitalize on advantages that are unique to satellite. For example, it can be much easier to add locations to a VSAT network than to a multidrop line network. Service providers or equipment suppliers can use this advantage to provide more responsive service.

6.1.2.2 Post 1992: Mesh VSAT. Mesh VSAT systems are under commercial development. Mesh VSAT systems are not yet ready for widespread commercial use, but the technological advances described in section 4 are likely to make this solution cost competitive within the forecast horizon of this study.

Mesh VSAT systems have been evolving along with hubbed VSAT technology. Two basic concepts are under development: baseband processing and frequency selection.

The first concept, baseband processing, is exemplified by NASA's ACTS, which will test baseband processing in addition to fast-hopping spot beams and Ka-band frequencies.

Spot beam technology reuses frequencies through spatial and polarization diversity. This conserves limited spectral resources. Using orderwire demand assignment, the satellite can allocate transponder capacity to accommodate multiple footprints with different levels of demand.

Onboard signal processing can switch and route individual circuits to create "mesh-like" single-hop routes between any two users. Advanced onboard electronics also provide an improved signal-to-noise ratio compatible with a bit error rate of 10^{-6}.

Use of Ka-band frequencies provides ACTS with a vast nominal bandwidth of 1,000 MHz, reducing the cost per unit of transmission capacity. However, an impediment to Ka-band transmission is higher atmospheric absorption. The ACTS combats fade at higher frequencies with adaptive rain-fade compensation. This innovation senses fade at each earth terminal using downlink beacons and adapts transmission rates accordingly. The integration made possible by ACTS technology tailors satellite service to the precipitation conditions of each user.

The second concept is frequency selection, which underpins some commercial satellite concepts. A frequency selection architecture uses a series of filters to distinguish transmissions among origin-destination pairs.

Satellites based on frequency selection are technically feasible now without further research and development. Hopping spot beams, however, would require commercialization and system optimization before deployment. Hopping spot beams are only one of several technologies being tested on the ACTS platform. As such, the platform could not be optimized for commercial viability. This optimization process would entail selection of a complementary subset of the most commercially promising technologies tested on ACTS. The optimization process would require 1 to 3 years for system engineering and cost analysis.

With a 1992 pricing structure, mesh VSAT is not cost competitive. Mesh VSAT terminals usually assume some hub functions, leading to increases in their cost. Current vendor estimates are approximately $50,000 per terminal. Although hub costs are considerably reduced, this does not offset the increased cost per user relative to conventional VSAT systems.

To project when mesh VSAT will become competitive, this analysis assumes that earth station prices will decline as rapidly as conventional VSAT in the near term. This implies a 25-percent cost reduction per year, which parallels the decline in conventional VSAT costs from $12,000 in 1989 to $5,000 in 1992. Over a short period, annual cost reductions of 25 percent are consistent with 50-percent unit sales growth and a steep (70-percent) learning curve. Neither the growth rate nor the learning curve is implausible, given the minimal current experience with this technology. Achieving high unit sales growth may be possible by exploiting small niches requiring specialized technical features, even before the technology is cost competitive. Even without sustained sales growth, design advances are likely to cut the cost of equipment.

Recurring VSAT costs are held constant during the evaluation period, because declines in VSAT price will not affect the cost of a particular system after hardware is procured. Terrestrial costs are increased by 1 percent per year, according to the price cap assumption explained in section 6.1.2.

This analysis changes mesh VSAT earth segment costs while holding space segment costs constant. Space segment costs are difficult to anticipate, because they represent multiple possible solutions to the system engineering problem of optimizing *total network* cost. The system engineering process for mesh VSAT involves sharing space segment cost among the optimal number of users. Figure 6-13 is a notional illustration of the tradeoffs involved. As the engineered transmission capacity of the satellite increases, the complexity of the system, and hence its cost, rises at an increasing rate. This is shown by the upper curve in figure 6-13. Space segment cost per user declines, however, because satellite cost is shared among an increasing number of users. With either frequency selection or hopping spot beam technology, a point will be reached at which incremental capacity costs offset the cost-sharing potential of additional users. At this point, the system is optimally engineered.

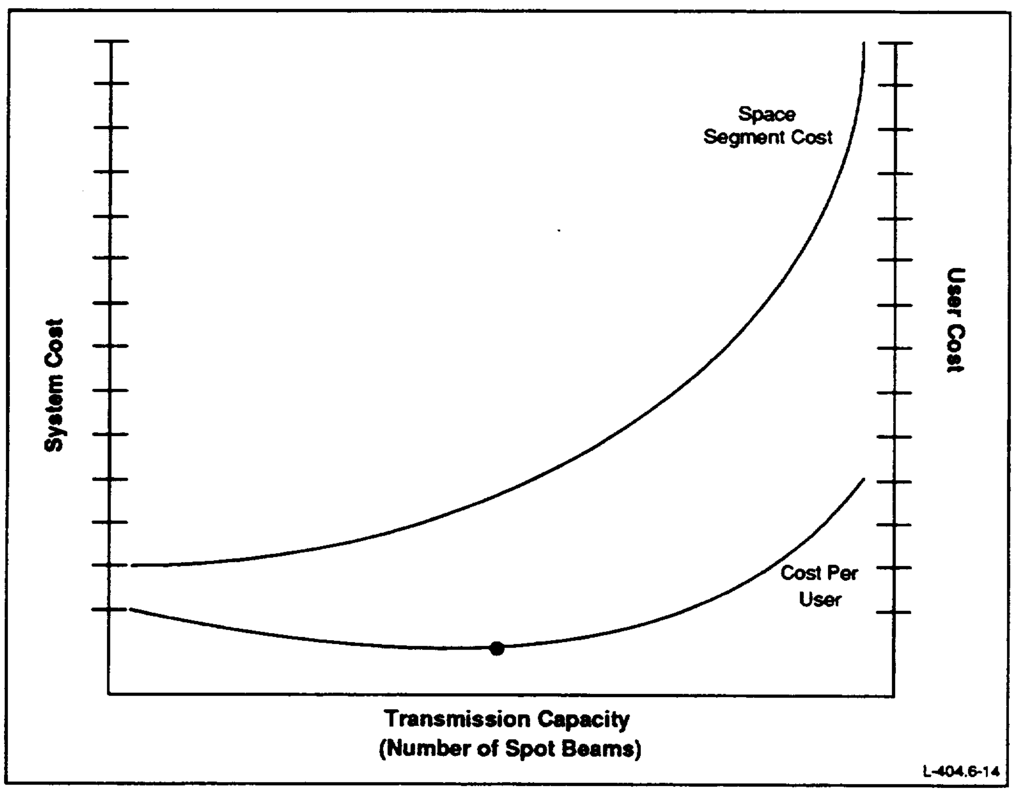
It should be noted that this engineering process differs from the problem of minimizing per-bit cost. Parker and Rinde (September 1988) have noted that this method of system design can lead to networks with higher data rates or larger antennas than required by the application, which reduces the capturable share of a cost-sensitive market.

The satellite system cost function is not as smooth as indicated in figure 6-13. Cost increases abruptly when the capacity or functionality of a satellite payload exceeds the capacity of standard satellite busses in terms of power or volume. Therefore, another important consideration in satellite cost optimization is to keep payload requirements within the limits imposed by commercially available bus designs. Advances in VLSI semiconductor technology will simplify the task of accommodating available bus designs, because they increase the potential to miniaturize satellite hardware and integrate related functions. As chips incorporate more and more of the functions of a switch or amplifier, reduced mass and structural complexity will improve satellite technology without sacrificing the cost advantages of standard buses.

The space segment cost curve in figure 6-13 can be shifted up or down by distributing processing between onboard and terrestrial facilities, by balancing terminal sensitivity and transponder power, or by modulating satellite complexity. For example, space segment complexity can be reduced late in the forecast horizon by deploying "smallsats." Smallsats are simpler processors appropriate for a limited region or user community. Smallsat capacity is augmented by launching additional satellites. Smallsats reduce the cost of key operational subsystems. Their scope for cost control is limited because redundant antennas and power subsystems offset reductions in system engineering complexity.

Smallsats may mitigate an important problem of satellite technology. Communications satellite technologies have unique economic features that increase risks. All communications technologies have high fixed costs—an infrastructure must be installed and maintained at a relatively constant level, regardless of variations in demand. This subjects communications suppliers to the risk of variations in capacity utilization and revenue per dollar of investment.

FIGURE 6-13
Mesh VSAT Optimization



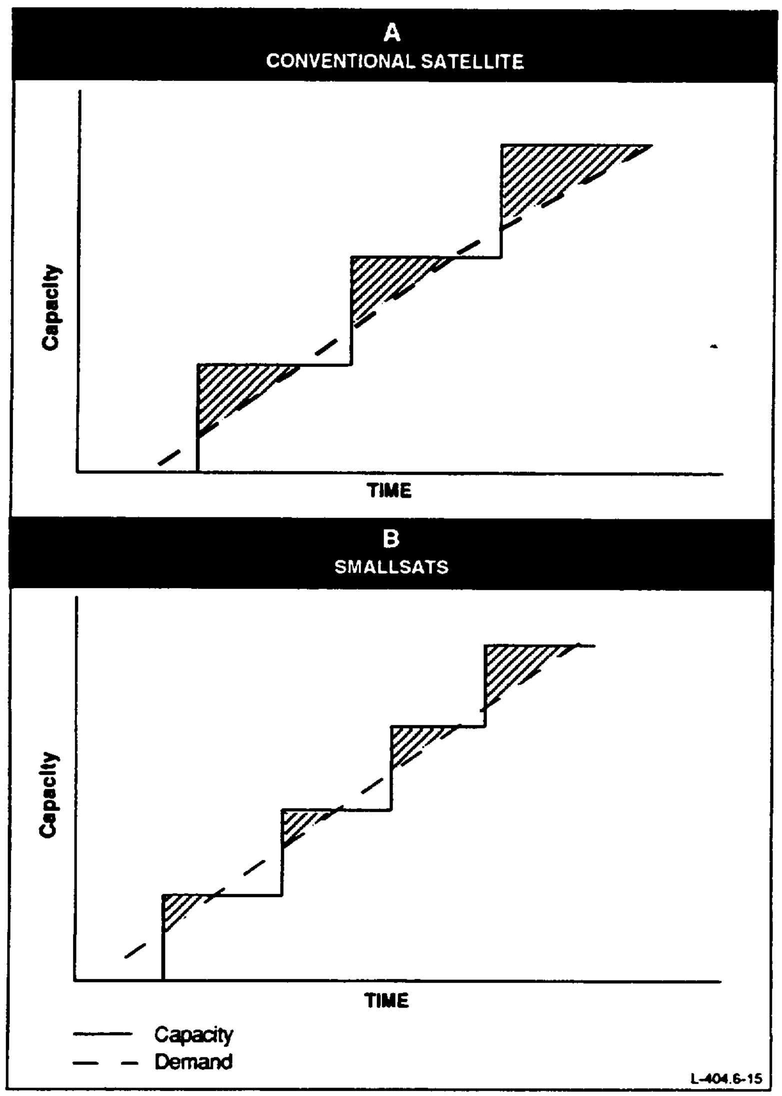
Source: Booz·Allen & Hamilton

Satellite communications compound uncertain demand with additional risks. The investment required is almost entirely "up-front." Substantially all investment resources must be committed and financed before any revenue is generated. Terrestrial carriers have the option of incremental expansion, but the space segment of satellite systems is normally monolithic. Satellite carriers can invest incrementally only in the earth segment—but the earth segment has declined as a proportion of system cost, and more of its cost has been absorbed by users. When planning a satellite service, providers normally must stake their full investment on uncertain markets. After launch, this investment has a strictly limited life. Expendables (such as fuel for stationkeeping) limit a carrier's ability to wait out periods of limited demand. These risks boost the required cost of financing; for satellite systems serving new markets, potential investors may demand a target internal rate of return that is double the prime rate.

Smallsats reduce carriers' initial capital requirements by permitting phased service expansion. This reduces risk, which can translate directly into cost savings when financing is secured.

Figure 6-14 illustrates a typical pattern of satellite capacity utilization and shows how smallsats can reduce risks by bringing revenues and costs into closer alignment. The step function in figure 6-14(a) shows how satellite capacity increases in discrete steps with each launch. Demand increases more smoothly; the result is usually unsold capacity or unmet demand. Unsold transmission capacity is shaded in figure 6-14. Idle transmission capacity can be minimized by preselling users in advance of launch.

FIGURE 6-14 (a&b)
Smallsat



Source: Booz·Allen & Hamilton

Figure 6-14(b) shows that smaller capacity increments limit the initial idle capacity of a satellite system. In addition, smaller satellites may be easier to presell to capacity.

Commercial developers are considering another means of reducing idle capacity. Multiuse satellites can provide immediately salable services as well as mesh VSAT. Satellites can be equipped to provide receive-only video service while VSAT applications are being demonstrated and sold. Since VSAT services do not replace video applications (the two services are intended to coexist on the satellite), multiuse is really just another means of reducing the capacity increment provided by a single launch. The potential market for increased video channels would seem to be very large. On the demand side, cable TV operators are beginning to upgrade systems to carry as many as 500 channels. On the supply side, the growth will come from narrowcasting. Some areas that have been implemented or discussed are comedy channels, science fiction channels, cartoon channels, opera channels (Italian, German, light, etc.), and specialized shopping channels.

Mesh VSAT technology provides designers with three degrees of freedom for controlling space segment cost per user: system optimization, smallsats, and multiuse options. Consequently, it is reasonable to assume that space segment costs can be held to a level comparable with current space segment resources.

Figure 6-15 summarizes the results under the conditions described above. Until 1998, mesh VSAT is not cost competitive for any segment shown in figure 6-15. But in 1998, a substantial fraction of the most dispersed networks will come within reach because rapidly declining terminal cost will fall below $9,000. Networks with 200 nodes are cost-effective mesh VSAT applications if users average 175 miles apart. VSAT may be cost competitive if users average just 125 miles apart. In 1 year, the market share that mesh VSAT can capture on a cost basis jumps from near zero to more than 50 percent—the shaded cells in figure 6-15, weighted by the corresponding shares in figure 6-9.

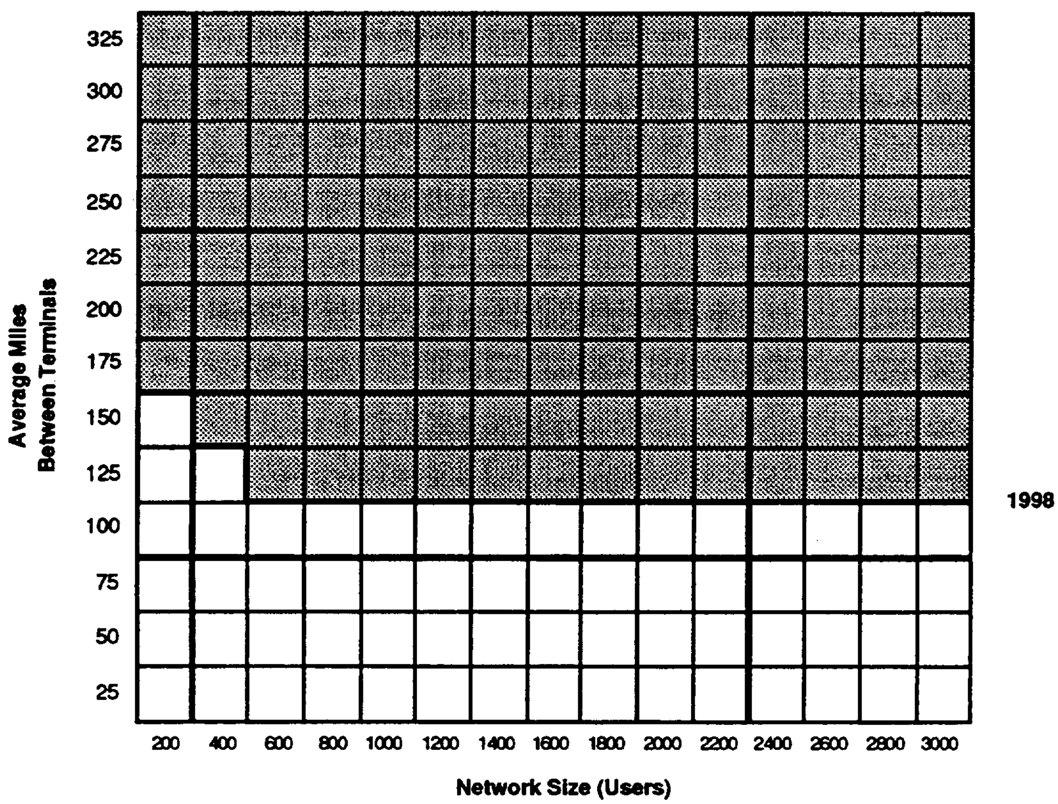
A study by Comsat, Mar-Tech Strategies, and Space Systems Loral estimates North American gross market potential at between 400,000 and 600,000 terminals in 1998 (Heltai 15 May 1992). This implies potential capturability of 250,000 users (50 percent of the 500,000 midpoint of the range).

This result depends strongly on the assumed 25 percent annual reduction in earth station cost. If VSAT earth station cost declines by 20 percent per year, in 1998 a mesh VSAT solution will be more costly for any segment shown in figure 6-15. By 1999, only 21 percent of the market will be capturable.

Under the conservative assumption of 20 percent annual earth station cost reduction, we can state that by 1999, 21 percent of users will definitely choose mesh VSAT over other alternatives if cost is the sole consideration. Of course, market penetration will lag behind its full potential because the innovation must diffuse through the user community. The private network market will have significant factors that will retard acceptance of mesh VSAT innovations, whether potential customers are using terrestrial or satellite networks. Terrestrial network users will have established relationships with competing suppliers. Under these circumstances, a telecom manager's decision to use a new source or technology risks criticism for any resulting problems. Satellite network users may also have inhibiting influences—for example, significant investment in conventional VSAT systems. On the other hand, mesh connectivity constitutes a significant performance advantage for satellite systems. Private-line networks are most cost-effective when they mediate interuser communication through a hub. This may increase response time and conflict with distributed applications. Virtual private networks provide service that is more comparable to mesh VSAT, but at a higher cost.

It is likely that after 1998, price declines will moderate while mesh VSAT systems diffuse through an increasing percentage of the capturable market until BISDN is widely available. At that point, growth will be limited to remote users not served by BISDN. Mesh VSAT will not necessarily cannibalize business from hub and spoke systems, however. Hub and spoke architectures are likely to remain attractive for applications where communications are primarily between remote sites and a single hub.

FIGURE 6-15
1998 Satellite Capture Potential—Private Data Networks



ASSUMPTIONS

- 6 Drops/Line
- 5 Year Economic Life
- 25% Per Year Price decline in terrestrial VSAT equipment

L-404.6-1s

Source: Booz·Allen analysis

6.1.3 BISDN Service for Remote Locations

One specialized application for VSAT technology would be connection of remote users to ATM switches. This application could connect a leased or user-purchased VSAT terminal to a BISDN switch in the PSN. Satellite transmission would augment inadequate terrestrial transmission, providing a broadband gateway to advanced PSN services. The service provided would differ from that of currently used VSAT systems because the connection would be user to network rather than user to user.

Research network managers currently estimate that only 1 percent of their users are relying on terrestrial microwave connections. If research networks are used as an analog for future BISDN users, this suggests that, at most, 1 percent of BISDN traffic can be captured by satellite. However, a 1 percent share of all the services BISDN could provide would be substantial in the later years of the forecast horizon. At the least, this additional source of traffic could diversify the revenues of the type of multiuse VSAT discussed in section 2.1.2.2.

6.2 BROADCASTING/DIRECT BROADCAST SATELLITE

Broadcasting markets have different characteristics than private network telecommunications markets. Competitive viability in broadcast markets results not from traffic-based revenues, but from charges to users or advertisers. For this reason, the competitive position of broadcast media is unrelated to the number of user channels—competitive position depends on the revenue that can be generated from the content of a limited number of channels. Also, in the consumer market for broadcast entertainment, subjective criteria play an important role, by comparison with the VSAT market. DBS technology can be used to transmit audio or video.

6.2.1 DBS Video

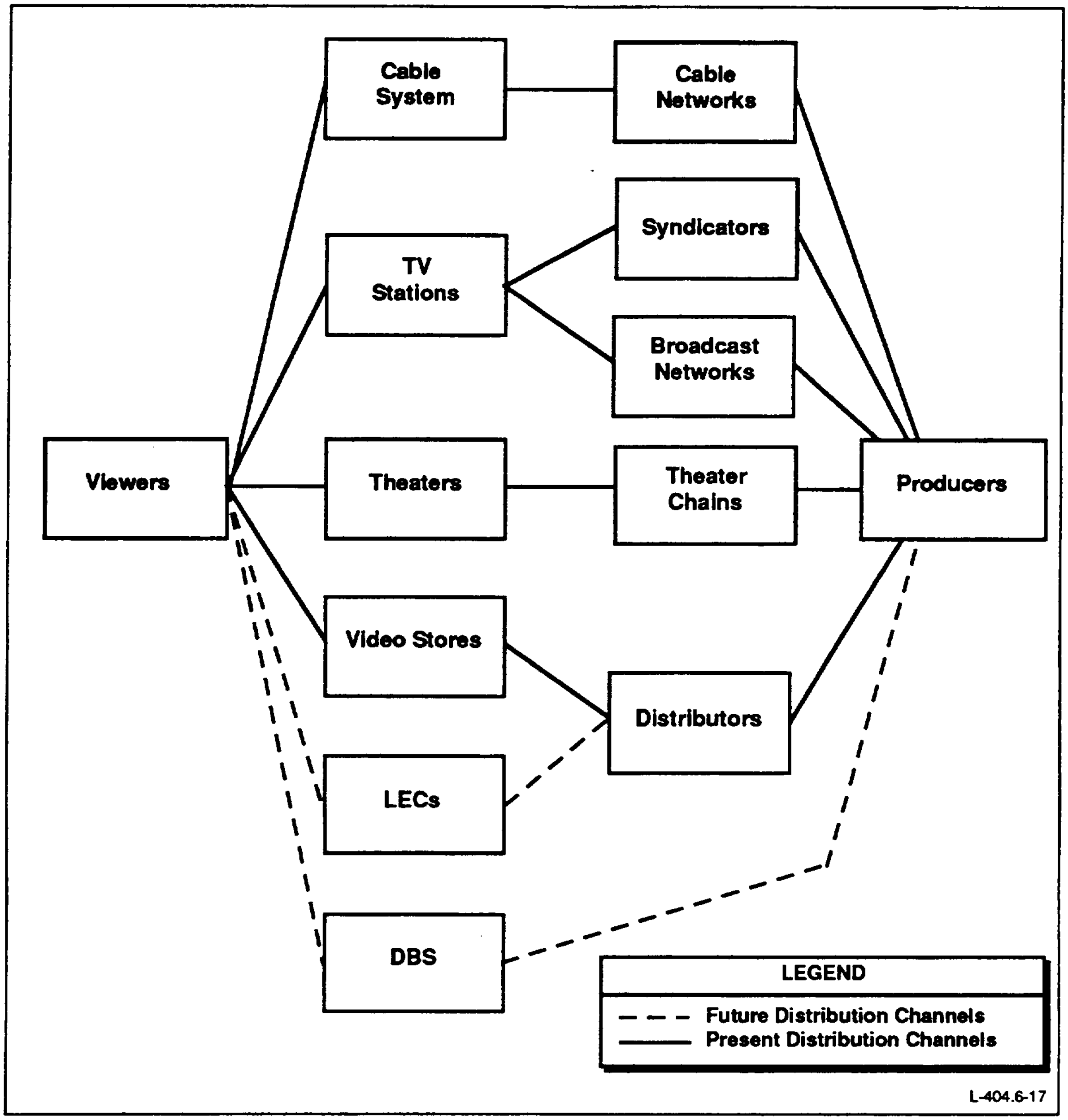
DBS video is satellite transmission of video programming to individual viewer terminals. The section below analyzes the characteristics of DBS video that determine its competitive standing in relation to other modes of video delivery.

6.2.1.1 Existing Industry Structure. Blaise Heltai of AT&T Bell Laboratories describes video broadcasting as an industry that is driven by services rather than technology (Heltai May 1992). In this industry, satellite technology will be of value to consumers if it cuts cost or increases convenience. But satellite technology will probably not provide new capabilities that change the competitive dynamics of the industry.

The structure of the video broadcasting industry is complex, with multiple competing media. Figure 6-16 summarizes the industry as described by Heltai and other industry observers. The left side of figure 6-16 shows that viewers are served by cable systems, VHF and UHF television stations, theaters, and video stores. Cable systems are granted local monopolies to serve the 88 percent of viewers whose homes are passed by cable. There are 1,470 conventional television stations that compete in regional markets: 1,117 commercial stations, about evenly divided between VHF and UHF, and 353 public stations, of which 129 are VHF. Many stations are affiliates of one of 4 national commercial networks, 22 regional networks, and 1 public network (Willis and Aldridge 1992).

Two potential industry entrants are shown at the lower left of figure 6-16. Several DBS ventures plan availability in the near future. Local exchange carriers are testing VOD delivered over telephone local loops.

FIGURE 6-16
Video Industry Structure



Source: Booz·Allen & Hamilton

VOD programming would be delivered in digital form over telephone subscribers' local loops. Fiber optic local loops would be natural candidates for VOD, but wire pair local loops can be used to deliver the service during the long transition to fiber to the home. The key enabling technology for video delivery over the vast preponderance of wire pair local loops is ADSL.

ADSL permits wideband transmission from network to customer and narrowband (either POTS or ISDN) transmission from customer to network. Northern Telecom, an ADSL supplier, envisions a regime of open network access to information providers, with multiple competing video services available over the local loop (Boyd 1992). Use of ADSL by competing services has the potential to force dramatic changes in the industry structure. ADSL may eventually render video stores obsolete as video chains migrate to optical jukeboxes for home control by viewers. Optical jukeboxes would be located at the premises of the video distributor. A jukebox would read digital video from high-capacity optical disks for transmission to an individual viewer. The jukebox could be controlled by narrowband data messages from a remote-control keypad in the viewer's home.

Each system receives programming from a different source or combination of sources. Vertically integrated cable companies provide programming to local systems through regional or nationwide networks. TV stations obtain programming from syndicators or a broadcast network to supplement programming with local content. Theater programming is often provided by agreements negotiated between theater chains and producers. Video stores rely on program distributors for programming on cassettes for home use. LECs are planning to obtain programming from video franchises' program distributors. DBS services could obtain programming directly from producers as networks do, on the strength of their broad regional or nationwide coverage.

The right side of figure 6-16 shows a single, highly concentrated source of programming. Program producers have substantial market power and thus substantial control over the timing and availability of programs.

Each of the existing distribution modes has strengths and weaknesses. Cable provides convenient access to a variety of programming. Television is the least-cost alternative. Theaters provide the earliest access to certain types of programming, along with high image quality on a large screen and high fidelity sound. Video stores offer the greatest degree of user control over program content and scheduling.

On the other hand, television and, to a lesser extent, cable are hampered by constraints on advertising revenues. Remote controls and video cassette recorders have reduced the effectiveness of advertising, and this effect is reflected in flat advertising revenues on a per-person, per-minute basis. Theaters, which often must compete for a small segment of the most lucrative programming, may be constrained by distribution agreements that restrict their ability to change programming and adapt to viewer demand. Video stores are perceived as inconvenient because rentals require two car trips for each viewing. Each of these more established modes, however, has far greater penetration and user familiarity than the potential new entrants—LEC video-on-demand and DBS.

Given the diversity of the industry at the customer interface, video services firms compete for narrow niches. These niches may be temporally defined, to exploit the practice of releasing major programs to different distribution channels in a specific sequence. Different distribution "windows" allow broadcasters to offer price-inelastic customers priority access to novel content, although producers tend to place all premium channels in the same window. Niches may be defined by program content as well. Distribution modes with direct access to the home offer news, weather, and other content with substantial time value. Cable companies use their relatively large number of channels to target small groups of users very selectively, while networks focus on general-interest programming.

In the video industry, the success of each distribution mode depends strongly on qualitative factors as well as cost. For this reason, the analysis in this section estimates DBS market capture potential by constructing a multiattribute utility model and applying it to specific market segments.

The model used in this analysis concentrates on factors related to the distribution mode and isolates them from factors related to programming. It is conceivable that a DBS service could establish business relationships with program producers that give it a competitive advantage through preferential access to attractive programming. However, the market power of program producers makes it unlikely that a new distribution technology will gain exclusive access to any type of programming because it is in the interest of producers (and in their power) to promote competition in the delivery of program products. Furthermore, industry sources are divided on the importance of programming as a revenue-generating factor. Heltai believes that programming has little effect on total viewing. GTE's trials with near-video-on-demand, however, show some correlation between buy rates and the strength of movie offerings.

6.2.1.2 DBS Competitive Capture Potential. Figure 6-17 summarizes the factors used here to represent a video distribution system's attractiveness to viewers. Cost and convenience are the two general factors affecting acceptance of a video delivery system.

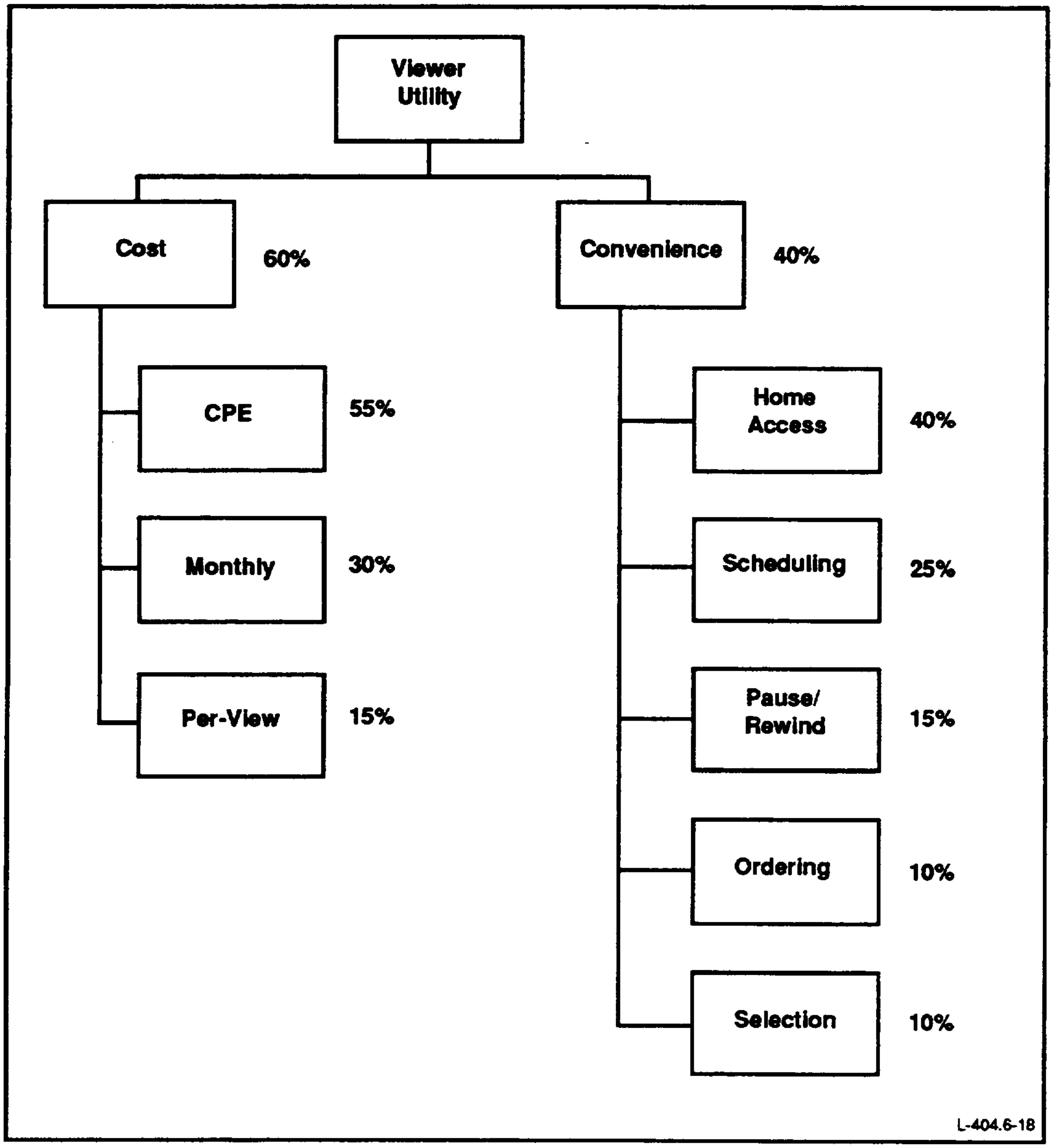
Cost can be divided into three primary subfactors. In contrast to the model in section 6.1, individual cost elements are not combined and discounted into a life-cycle cost index because household decisions may exhibit a preference for incremental payment even if total costs are higher. In addition, households can modulate their viewing patterns to influence cost to a greater extent than commercial VSAT users.

Customer Premises Equipment (CPE) is the first cost element. This includes equipment that viewers must purchase to access programming. For example, the CPE needed to use video stores is a video cassette player. In addition to CPE, fixed (usually monthly) recurring subscription charges may be levied on users. Finally, the video delivery system may also have a ***per-view*** payment for some programs. This analysis uses average monthly pay-per-view cost.

Convenience is a combination of several features that market studies have shown to be of value to video viewers. ***Home access***, the ability to order and obtain programming without leaving home, is one advantage not available to video stores or theaters. ***Scheduling*** flexibility, a viewer's ability to view a program at the time of his choosing, is also important to users. Market studies of video-on-demand have shown that ***pause and rewind*** capability is very important to viewers. The simplicity of program ***selection*** is another factor in viewer satisfaction. Selection convenience depends on the answers to the following questions: How easy is it to scan available offerings? How easy is it to find an offering that satisfies the viewer's general criteria? The simplicity of ***ordering*** a program is important to viewers but highly subjective. Online menus are preferable for some viewers, while telephone order lines are more familiar and desirable for others.

Figure 6-17 assigns weights to the importance of each factor. The importance weights are selected for consistency with consumers' priorities, as shown in recent surveys. The numerical weights are used to permit consistent calculations, but the weights are less important than the importance ranking of the factors. At the top level, overall cost, at 60 percent, is weighted somewhat higher than general convenience (40 percent). This reflects the fact that viewers seem willing to pay for increased flexibility and simpler control, but price resistance is significant if prices are substantially above those of video stores. In addition, market tests of home video services indicate that nonusers cite price as the main obstacle to use (Broitman 15 May 1992).

FIGURE 6-17
Video Viewer Utility Model



Source: Booz·Allen & Hamilton

Cost subfactors are weighted according to their likely effect on service adoption. For example, purchase of CPE poses a risk to viewers in the event that they do not adopt the service. CPE is a discrete, initial cost that often must be incurred before the service can be evaluated. For this reason, it receives the highest weight, 55 percent. Monthly costs can be discontinued if the service is not adopted, but they are independent of service use. For this reason, fixed charges also have some potential to deter new viewers. Since fixed charges are less of an obstacle to service adoption, they are weighted at 30 percent. Per-view cost is directly related to the programming purchased. Video-on-demand market studies often charge on a purely per-view basis to maximize adoption. Per-view costs are weighted at 15 percent to reflect their modest disincentive effect on service trial and adoption.

Of course, operators of a video system can amortize initial costs or allocate fixed costs to usage to make the price structure more palatable to customers. However, costs are likely to be lowest if they conform to the cost relationships governing the technology. For example, CPE leasing raises costs for most users. Similarly, a policy of recouping fixed charges on a per-use basis may raise costs for frequent users and inhibit use of the system.

Among convenience factors, home access is weighted most heavily, with 40 percent. Home services have been shown to replace video store use in LEC video-on-demand trials. Scheduling is the next most important feature, at 25 percent, because it ensures that viewers can suit a particular offering to their schedule. Market trials of systems that offer home access and scheduling control indicate that pause and rewind capability is the most important feature cited by viewers (Kennedy 15 May 1992). Pause and rewind capability is weighted 15 percent. The closely related ordering and selection features are each rated at 10 percent.

The next step in this analysis is to evaluate the delivery modes in figure 6-16 from the consumer's viewpoint according to the criteria of figure 6-17. Figure 6-18 organizes this evaluation in the form of a tabular worksheet. Rows correspond to the competing modes of video delivery. Columns are assigned to each of the most specific user criteria. Cable, TV, theater, and the other competing systems are described with a set of categories that is distinct for each column.

CPE cost is evaluated in terms of equipment price ranges: under $100, the breakpoint represented by a low-end, play-only VCR; $100–$200; $200–$400; or more than $400. Note that CPE cost does not include the cost of a television, because televisions are ubiquitous and much ancillary equipment can be added to the television on a modular basis. Monthly cost of a typical system is also assigned to a range: under $10 (including $0), $10–$20, or more than $20. Average per-view cost can fall into the categories under $2, $2–$4, $4–$6, or more than $6.

Home access can provide low, medium, or high convenience. A delivery mode providing low convenience requires the user to view the program outside the home. Medium convenience requires the viewer to leave home to order and obtain the programming but permits home viewing. High-convenience delivery modes permit home ordering and home viewing.

Scheduling also has three qualitatively different utility ratings. One-time (1X) scheduling requires the user to make provisions to watch or record a program at the time it is broadcast. Scheduling may also provide flexibility to the user by repeating programs, thereby permitting the user to choose different viewing times after a wait ranging from 15 minutes to a day or more. This level of scheduling convenience is indicated on figure 6-18 as (W). Complete (C) scheduling flexibility lets the viewer choose when to start the program.

Pause and rewind capability is indicated with binary categories: the user has control (Yes) or not (No).

Ordering and selection convenience are also rated low, medium, or high. High ordering convenience permits program selection with a remote control or menu-guided display. Medium convenience permits phone-in or personal order transactions. Low-convenience ordering is distinguished from the other categories because the order is placed in one location (e.g., a video store) and the program is viewed in another (e.g., the home). High selection convenience permits random home access to the full program inventory. Medium selection convenience restricts the user to serial access ("barker channels") or manual perusal of the inventory. Low selection convenience requires the viewer to research the availability or location of his choices.

FIGURE 6-18
Video Delivery Mode Factors and Categories

	COST			CONVENIENCE				
	CPE	Monthly	Per-View	Home Access	Scheduling	Pause/Rewind	Ordering	Selection
Cable	>100	>20	>6	High	1X	No	Med	Med
TV	0	0	0	High	1X	No	High	Med
Theater	0	0	>6	Low	W	No	Med	Low
Video Store	100–200	0	2–4	Med	C	Yes	Low	Med
LEC VOD	200–400	10–20	2–4	High	C	Yes	High	High
DBS	200–400	<10	0	High	W	No	Med	Med

Source: Booz·Allen & Hamilton

An important assumption of this scenario is shown on the bottom row of figure 6-18. The DBS system posited in figure 6-18 is less expensive, but also less capable, than the most elaborate one that DBS technology can support. It presumes terminals available in the range of $200 to $400 that do not support user transmissions for program control. Advertising is assumed to be the primary revenue source, which keeps both monthly costs and average pay-per-view charges to a minimum. Scheduling flexibility is provided by repeated programming because VCR-type controls —pause, rewind and play—are not available. Any pay-per-view ordering is accomplished over 800 lines from the viewer's telephone, and program selections are announced with barker channels.

For the purposes of this analysis, values are assigned to cost ranges and convenience categories to represent consumer preferences. Most recent market survey results are considered proprietary, but industry experts have discussed the relative importance of features to the consumer. The ratings used here are selected to represent how consumers in market tests rank features in order of preference.

To apply the ratings to each competing delivery system, this analysis uses the Analytic Hierarchy Process (AHP). This is a means of representing decisions where consumer preferences and priorities are distinguished on a ratio scale or in terms of categories. The AHP technique permits realistic representation of consumer choices between pairs of alternatives where no scale of measurement exists. The assumption of the AHP is that decisions, such as consumer purchases, are a series of dichotomous (or "pairwise") choices. Pairwise choices are consistent with standard techniques of attitude scale construction. Multiple pairwise comparisons permit measurement of consistency.

The relative values of cost and convenience ratings and the relative importance of cost and convenience factors are judgments made by the Booz·Allen authors. The authors assigned numerical values to ratings and factors for internal consistency and for ordinal consistency with publicly available market research data. The model does not represent actual survey data; it is a sensitivity analysis of possible consumer preferences. This means that rankings, not numerical values, are the primary model results.

Figure 6-19 shows consumer preference rankings for the six video delivery modes. These rankings are the output of the AHP model, given the importance weights shown in figure 6-17 and the descriptive categories shown in figure 6-18. Rankings are displayed for three notional types of consumers or market segments:

- Price-sensitive viewers, for whom price as a whole is more important than convenience. Preferences of these viewers are modeled with a 60-percent weight on overall cost and a 40-percent weight on convenience, as shown in figure 6-17.

- Equal-importance viewers, who trade off price and convenience on equal terms ("twice" as much convenience justifies a doubling of price). To model the preferences of these viewers, the weights in figure 6-17 are modified to be 50 percent cost and convenience weightings.

- Convenience-sensitive viewers, who value convenience more highly than price savings. The model represents these viewers by weighting cost 40 percent and convenience 60 percent.

Television is the highest rated delivery mode for all three market segments. This reflects the fact that for most viewers, the television set is a sunk cost, and television programming is available without fixed monthly charges or per-view costs. Television is a basic capability where reception is acceptable, and its acceptance is correspondingly high.

In market segments where convenience is more important, the other delivery modes change their relative attractiveness. VOD provided by LECs moves to second place behind television because of its ability to combine VCR functionality with menu-driven ordering and selection at the home terminal. Cable declines in attractiveness because its higher costs interact with convenience features that are not much better than those of television. DBS is the least attractive delivery mode for price-sensitive market segments, but it is more attractive than theaters for segments where convenience is more important. This is because DBS offers home access and greater selection convenience than theaters. DBS is also more attractive than cable because of the potentially lower cost of an advertising-oriented service.

FIGURE 6-19
Video Delivery Mode Preference Rankings

	COST			CONVENIENCE							
	CPE	Monthly	Per-View	Home Access	Scheduling	Pause/Rewind	Ordering	Selection	Price Sensitive Consumer	Equal Importance Consumer	Convenience-Sensitive Consumer
Cable	>100	>20	>6	HIGH	1X	NO	MED	MED	5	5	5
TV	0	0	0	HIGH	1X	NO	HIGH	MED	1	1	1
Theater	0	0	>6	LOW	W	NO	MED	LOW	3	6	6
Video Store	100-200	0	2-4	MED	C	YES	LOW	MED	2	3	3
LEC VOD	200-400	10-20	2-4	HIGH	C	YES	HIGH	HIGH	4	2	2
DBS	200-400	<10	0	HIGH	W	NO	MED	MED	6	4	4

Source: Booz·Allen & Hamilton L-404.6-20

Although DBS is rated less attractive than some competing delivery modes, this does not mean that it will not be chosen by consumers. All of the four currently prevalent services—cable, television, theaters, and video stores—coexist in most areas. Individual viewers often use several services because services occupy niches defined by program content or novelty and because viewers' strength of preference for program content and convenience changes continually.

Marketing strategies for past service tests have relied on the coexistence of multiple delivery modes. K Prime perceived its market as viewers who seek all available services. Still, their expected take rates varied with the alternatives: 11.6 percent of uncabled subscribers versus 6.6 percent of cable subscribers (*Broadcasting* 29 October 1990, 119:57).

Another obvious niche for DBS is based on location. Areas where some alternatives are distant or unavailable are more likely to adopt and use DBS. For example, the 12 percent (as of 1990) of homes not passed by cable are a natural market. Areas with poor television reception have long been natural DBS niches, particularly if they are remote. Areas with low population density handicap services like video stores and theaters that do not offer home access. In the future, the single most ubiquitous competitor to DBS will probably be LEC VOD offerings. These are potentially available to all telephone subscribers. However, two-wire local loops are unable to support the ADSL service, and two-wire local loops are by far the most common current transmission medium. Over time, two-wire local loops will be replaced with fiber. This will increase the potential subscriber base of LEC video coverage.

Figure 6-20 summarizes the results of a sensitivity analysis on DBS terminal cost. The AHP was used to compare DBS to other delivery modes under the assumption that DBS earth terminal costs are reduced. Figure 6-20 shows that the relative attractiveness of DBS increases dramatically, to second or third place, if earth station prices fall into the $100 to $200 range. This is consistent with Heltai's observation that low-cost video delivery can confer powerful competitive advantages.

FIGURE 6-20
Sensitivity Analysis: Low-Cost Antennas

	COST				CONVENIENCE						
	CPE	Monthly	Per-View	Home Access	Scheduling	Pause/Rewind	Ordering	Selection	Price-Sensitive Consumer	Equal-Importance Consumer	Convenience-Sensitive Consumer
Cable									6	5	5
TV									1	1	1
Theater									4	6	6
Video Store									3	4	4
LEC VOD									5	2	2
DBS	100–200								2	3	3

Source: Booz·Allen analysis

An assumption that the average cost of pay-per-view and free offerings is less than $2 implies minimal reliance on pay-per-view. If both cable and DBS boost their proportion of PPV offerings to increase average per-view costs to the highest category, DBS becomes less attractive than video stores, even to convenience-sensitive users and markets. However, PPV is more profitable than advertising per hour of each viewer's time; therefore, lower levels of adoption and use may sustain a DBS service.

6.2.1.3 DBS and HDTV. The model described in 6.2.1.2 does not include image quality as a competitive factor. However, HDTV technology has the potential for making image quality an important factor in distinguishing many different delivery modes. The effect of HDTV on DBS will depend on the compatibility of transmission standards with satellite platforms. Current independent standardization processes in multiple countries revolve around the key issue of whether chosen standards should be analog or digital.

The FCC is testing five HDTV technologies with the intention of selecting a standard by the spring of 1993. The successful approach is almost certain to be a digital technology. DBS can take either form. British Satellite Broadcasting (BSB) used the analog MAC format developed by Phillips and Thomson. Sky Broadcasting, BSB's acquirer, uses a conventional 625-line PAL color television system. By contrast, the Hughes DBS satellite plans to use a digital DCT format based on the CCITT's MPEG standard (Edge Publishing 1992, 7:19).

Adoption of a digital standard would simplify the system engineering required to give HDTV capability to a satellite broadcasting compressed digital video. Low-power transmission from less expensive satellites would be possible and would not degrade the viewer's image quality. More importantly, if a carrier broadcasts digital HDTV images, the picture could be "stepped down" for viewing on less expensive 525- and 625-line color televisions. This would permit an HDTV broadcaster to reach viewers who have not yet purchased HDTV-compatible televisions. Set-top converters would be required, however. Industry sources estimate that these converters will cost $250 by late 1994 and will fall to $150 by 1997.

Adoption of a digital HDTV standard could give DBS an important competitive advantage. Under current FCC plans, terrestrial TV broadcasting would not be required to shift to HDTV until 2008. Cable companies converting from analog transmission would need to augment customer equipment with digital decoders. The cost of this upgrade might reduce the disadvantage DBS incurs by requiring special-purpose receivers. DBS could be the first medium to broadcast HDTV, using digital decoders that could interchangeably display HDTV and conventional-resolution TV. This would differentiate DBS from its terrestrial competitors and improve its competitive position. It may then be possible to price DBS services higher than other video offerings.

6.2.2 DBS Radio

DBS-R is satellite transmission of audio programming to receivers owned by individual consumers. The section below analyzes the characteristics of DBS radio that determine its competitive standing relative to terrestrial broadcasting systems.

6.2.2.1 Existing Industry Structure. Radio differs significantly from video. The two media serve different advertisers and reach audiences under different circumstances.

The existing terrestrial radio industry is much less concentrated than the television broadcasting industry and its markets are much more localized. The table below lists radio broadcasters by type:

Commercial AM:	4,986
Commercial FM:	4,402
Public AM:	22
Public FM:	1,442

The total number of radio broadcasters is 10,852, which is much larger than the number of television stations categorized in section 6.1.1. Commercial industry revenues totaled $7.3 billion in 1991. Typically, 75 to 80 percent of this revenue results from local spot sales, even at larger stations (Willis and Aldridge 1992).

Three-fourths of all AM stations are Class III, regional, or Class IV, local. FM broadcasting is inherently local, with even the most powerful station (Class C, Effective Radiated Power 100 kW) reaching listeners located within 70 miles. The local orientation of the industry is moderated to some extent by 8 national commercial networks, 101 regional commercial networks, and 31 format services. Some analysts saw significant consolidation of the broadcasting industry in the late 1980s, which increased the power of network radio sales representatives, programmers, syndicators, and networks (Norris 1987, 58:S18). Larger forces external to the industry, however, suppressed profits and increased the intensity of competition, as described in section 6.2.2.3. Two public networks coexist with commercial networks, drawing revenue from grants and voluntary subscriptions rather than advertisers.

Radio differs from television in another important way. The fixed supply of program offerings from the concentrated production industry makes television a relatively homogeneous product. By contrast, radio programming draws on a vast supply of current and old music, as well as talk-radio content that is relatively easy to produce or obtain through syndicators. As a result, radio stations compete by segmenting the market. Of the 15 most common distinct formats, none was used by more than 21 percent of all stations (Sherman 1987, 83). One current focus of industry concern is the proper degree of segmentation. If competing segments are too numerous and too similar, fragmentation of the market may result, along with a multitude of stations struggling with insufficient penetration in each segment.

Radio is usually characterized as a "background" medium; that is, radio programming is not the focus of household activity in a single place. Radio is an accompaniment to other activities, especially driving. Radio listeners choose between competing stations, unlike television viewers, who choose between competing programs. Although radio does not involve listeners as intensely as television, its ubiquity surpasses that of television. Radios are owned by 99.9 percent of the population. There are more than two radios per person nationally.

Habit plays an important role in the competitive status of radio stations. Promotion is an important factor in getting listeners to try a new station. Younger market segments change listening habits most readily, but news/talk formats draw an audience that may take 3 years to show significant change (U.S. Government Printing Office 1986).

Commercial radio's competitive structure and near-exclusive reliance on advertising make it vulnerable to consumer listening patterns. A recent study indicates that listeners are exposed to only about half of the advertisements played, because listeners avoid advertisements by switching stations (Abernathy 1992, 31:33–42).

Two types of audio services that would provide programming delivered by new technology are under test. These services, both digital, are cable radio and DBS-R. Analysts see cable radio as a premium service that will not rely on advertising support and will not compete directly with terrestrial stations for revenue (Rigney 1991, 62: 54–58). DBS-R has potential, however, as an advertiser-supported service and a subscription service.

Digital radio has powerful competitive advantages. It offers static-free, compact-disc-quality sound to listeners. This is significant because the quality of FM sound was one reason for FM's greater revenue and audience growth relative to AM. Another advantage of digital sound is the potential for multiplexing: FM broadcasters use multiplexing on a much smaller scale to diversify and supplement their revenue base with subcarrier leasing for Muzak, paging, and other services. DAB thus offers more of the competitive advantages of FM radio. Terrestrial radio stations also may adopt digital radio; the National Association of Broadcasters (NAB) is promoting the European Broadcasting Union's Eureka standard.

6.2.2.2 DBS Attributes. DBS-R has characteristics that are very different from those of the existing terrestrial radio broadcast industry. One important attribute is that a different receiver is required. This may compound the difficulty of influencing listening habits with the problem of selling a new type of consumer electronic product. Advertising revenue will depend on the penetration of satellite radio sets as well as the competitive position of terrestrial stations.

Another important attribute is that satellite is inherently suited to a national, or at least regional, audience. This has been the focus of a campaign against DBS-R by the NAB. NAB has adopted a resolution that digital satellite radio broadcasting will have a negative impact on "localism," and that terrestrial-only digital broadcasting should be developed (*Broadcasting* 2 July 1990, 119:57). While DBS-R using spot beams could broadcast different programs to different regions, its audience would inherently cover a much wider geographic area than any FM station and most AM stations. This may benefit ad sales efforts with economies of scale by attracting accounts from larger advertisers. And the consensus of industry experts is that network radio growth depends on the medium's ability to acquire and retain new advertisers (Norris 1987a). As a national medium, DBS may have an advantage in attracting these new advertisers.

A third key DBS-R attribute is that it can offer a large number of channels—up to 100 in some configurations (Weber 1991). This is an advantage because a larger number of satellite channels can more easily accommodate the preferences of precisely defined audiences. Satellite's high channel capacity is well suited to a finely segmented market.

6.2.2.3 Competitive Capture Potential. This section examines the feasibility of two potential DBS-R businesses: an advertising-supported service and a subscription-based service.

Figure 6-21 lists assumptions and results for a notional DBS-R venture supported by advertising. Figure 6-21 is not a standard pro-forma financial statement, but a cashflow analysis with supporting detail on revenues, expenses, and investments.

The fundamental market variable underpinning the DBS-R venture, the size of the *audience*, is shown at the top of figure 6-21. *Ad revenue* is calculated from the audience size, based on the assumptions discussed below. Three indented variables represent initial DBS-R costs. *Satellite cost* is shown as an initial expenditure in the third row of figure 6-21. The variable labeled *audience acquisition* determines the size of the audience in each year, given the assumptions discussed below. *Receiver development* is a direct input to the spreadsheet. Satellite cost, audience acquisition, and receiver development are summed into the variable *initial outlay*.

Four NAB standard categories of recurring expense—*programming*, *ad sales*, *general and administrative*, and *technical*—are derived from the assumptions discussed below and summed into the variable *operating cost*. *Operating cashflow* is calculated as ad revenue minus initial outlay and operating cost. *Taxes* are derived from a separate pro forma income statement not shown here, which makes assumptions about depreciation and tax loss carryforwards. Taxes are subtracted from operating profit to compute *cashflow*, which is reduced to an internal rate of return (IRR) as an overall measure of financial feasibility.

Assumptions. Key assumptions about the structure of the business include the following:

- Individual channels are managed by the satellite operator—the satellite operator is not merely a transmission service for independent programmers.

- Expenses for each channel are comparable to those of independent radio stations.

- An independent manufacturer finances and bears the risk of equipment development and marketing.

- The DBS-R venture is supported by advertising.

The first assumption was made to incorporate the competitive environment of the radio broadcasting industry into the analysis. DBS-R operators may or may not provide programming along with transmission. Satellite CD radio, for example, will distribute but not originate programming (Weber 1991). For the purpose of this analysis, combining the two businesses tests the transmission medium against the recurring costs it must support with its advertising reach.

FIGURE 6-21
DBS-R Cashflow Analysis, Advertising-Based Service
(Dollars in Millions)

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Audience (millions)	0	14	28	47	67	84	94	98	102	106
Ad Revenue	0	78	185	358	574	793	978	1110	1154	1200
Satellite Investment	230	330								
Audience Acquisition	300	300	400	400	300	150				
Receiver Development	10									
Initial Outlay	540	630	400	400	300	150	0	0	0	0
Expenses										
Programming	27	27	27	27	27	27	27	27	27	27
Ad Sales	22	22	22	22	22	22	22	22	22	22
General & Admin	36	36	36	36	36	36	36	36	36	36
Technical	5	5	5	5	5	5	5	5	5	5
Operating Cost	90	90	90	90	90	90	90	90	90	90
Pretax Cashflow	-630	-642	-305	-132	184	553	888	1020	1064	1110
Taxes	0	0	0	0	98	274	355	408	426	444
Cashflow	-630	-642	-305	-132	86	279	533	612	638	666
Internal Rate of Return	8%									
ASSUMPTIONS										
Acquisition $/listener	$21.90	(2 spots/day for 1 year @ $15 CPM / 50% take rate)								
Listener growth	4%	(without promotion)								
DBS-R CPM	$15.00									
Hours/Week	126									
Spots/Hour	10									
Spot Sellout Rate		30%	35%	40%	45%	50%	55%	60%	60%	60%
Program $ per Channel	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
Ad Sales $ per Channel	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
G&A per channel	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Technical $ per Channel	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
Number of Channels	30									

Source: Booz·Allen analysis

L-404.6-22

Multiple-channel broadcasting exploits the strengths of DBS-R. Advertisers often distribute their spots among different channels based on specific objectives. An advertiser may choose spots on several stations with similar audience demographics to maximize the chance that a particular audience will hear frequent repetitions of its commercials. Alternatively, the advertiser may purchase time on different types of stations to increase awareness in a broad cross section of the population (Kimball 1991, 11:9). Multiple-channel DBS-R could be the only source able to contribute to each type of advertising objective in many regions. DBS could collect more dollars per advertiser, which would increase the efficiency of its sales effort.

The second assumption is a conservative simplification of the way a network of satellite channels could be managed. Expenses were derived by analogy to NAB figures: programming constitutes 30 percent of a typical radio station's expenses, General and Administrative (G&A) cost constitutes 40 percent, sales are 25 percent, and technical expenses are 5 percent (Sherman 1987). In a centrally managed national network, G&A costs may be lower because duplication is eliminated, but sales are likely to be higher because of the larger national "territory." A figure of $900,000, representing moderately high radio station programming costs, was used as a benchmark for the other expense items.

The third assumption implies cooperation with a major equipment manufacturer in which the equipment manufacturer bears most of the cost and risk of producing DBS-capable radios for purchase by the DBS-R audience. The development figure of $10 million is primarily for systems engineering. It includes ground segment specifications and coordination with the satellite system architecture.

Assumption four is only one potential role for DBS-R. We relax this assumption later and repeat the analysis. An advertising-supported system implies a much larger audience. Since advertisers would have to choose whether to reach listeners with DBS or existing radio stations, DBS would be in direct competition with terrestrial radio stations. Most current ventures (for example, Satellite CD Radio) are targeted at the smaller market for pay subscribers to premium channels (Robert Briskman, telephone conversation, 22 June 1992).

The DBS-R market is represented by five key assumptions:

- Listeners are acquired in a radio campaign. A year of twice-daily spots produces a 50 percent take rate (50 percent of listeners adopt the service in the course of the year-long radio campaign). For simplicity, churn, or subscriber loss, is assumed to be zero.
- DBS-R radio cost per thousand (CPM) can be no higher than terrestrial radio rates.
- The audience grows at 4 percent per year without radio promotion.
- Spots are salable only from 6 a.m. to midnight, and a maximum of 10 spots per hour can be programmed.
- Each channel's spot sellout rate increases from 30 percent to 60 percent over 10 years.

The first assumption simplifies the listener acquisition process. Radio advertisement is a natural and inexpensive way to reach prospective DBS-R listeners. Radio promotion is also a good threshold condition for DBS-R viability—if a DBS-R business is not viable with inexpensive radio advertising, it is not likely to be viable if it has to advertise in more expensive media. However, multiple media are likely to be used to promote DBS-R. In addition, the independent equipment manufacturer may coordinate its efforts with those of the broadcaster.

Terrestrial radio industry sources perceive DBS-R as a competitive threat. It is possible that the terrestrial radio industry will erect barriers to satellite entry with discriminatory pricing or other conduct. For example, radio advertising boycotts are not unprecedented.

The second assumption is made by analogy to current radio competitive dynamics. Radio advertising rates are extremely sensitive to a station's rank within its market segment. Until DBS-R stations capture the highest rating for their format nationwide, DBS-R spot rates will probably be strictly limited by terrestrial radio rates. Among national advertisers, DBS-R may eventually command a CPM premium relative to terrestrial media because of its larger geographic coverage. DBS-R CPM may also rise if DBS-R overcomes perceptions of radio as a low-prestige medium.

A slow (4 percent) rate of growth is assumed in assumption 3 above to represent innovation diffusion through the customer base that is not dependent on the initial promotion.

The last two assumptions reflect typical constraints on a terrestrial station's spot sales. It may be possible to rationalize ad sales with multiple, centrally managed channels, but terrestrial competition is likely to exert a strong influence on advertising yield. Of course, if DBS-R can position itself as a distinct medium, its competitive environment may be very different from that assumed here.

The model used to integrate these assumptions makes no assumptions about financing. Cashflows are defined before financing, which could significantly alter their timing. This approach is used because it isolates business risk from financial risk. A DBS-R venture could be financed with various combinations of debt and equity, but its underlying business risk would be the same.

Results. The most important result of this analysis is that sufficient penetration of the national radio audience can support the capital expenditure of a DBS-R satellite. The advertising CPM of DBS-R can compete with terrestrial radio rates because the higher capital cost is offset by greater reach.

Although DBS-R is much more capital intensive than terrestrial radio, fixed investment is not the most significant initial cost. Promotion and marketing expenditures greatly exceed space segment investment. Space segment investment is based on three redundant satellites costing $100 million each. Two satellites are launched at $80 million per launch and insured for $50 million each. More than three times this amount is needed to create an audience that will provide a minimal 8 percent return in 10 years. Although a 10-year evaluation period is used for this analysis, strong radio listening habits and the need to sell new receivers reduce profit in the evaluation period. A longer evaluation period would show better results. In fact, the long maturation time of the business means that satellite reliability and economic life are important profitability factors.

Another factor affecting near-term profit prospects is that terrestrial radio is now suffering from a combination of excessive debt, declines in advertising sales linked to the recession, and increased competition (Ballman 1991, 18:1). Aggregate debt service exceeds revenue in some regions, which makes it impossible for some stations to cover fixed costs. Much of this debt was taken on to acquire stations in the mid-1980's, at speculative prices averaging 12 times cash flow. These prices would produce a return equal to risk-free Treasury securities in a no-growth environment; therefore, it is likely that purchasers expected substantial real cash flow growth to compensate them for business risk. Advertising revenue growth reversed, however, and turned negative in many regions as a consequence of the recession. Since most radio broadcasting cost is fixed with respect to revenue, profit was directly affected. Increased competition compounded the stations' problem. Starting in 1984, the FCC began to name more than 700 new FM station sites. It also permitted some stations to double their radiated power, allowing stations' dominant areas of influence to grow and, often, overlap.

The results displayed in figure 6-21 were selected to show the conditions under which DBS-R exceeds the threshold for business viability. An 8-percent internal rate of return (IRR) was selected as a minimum acceptable return. An 8-percent IRR is not the upper limit of DBS-R profitability, but the promotion needed to gain a commercially viable listener base requires significant negative cash flow in the early years. Uncertain service take rates and advertising sellout rates pose a greater risk than the technical and regulatory uncertainties affecting DBS-R. Industry sources for both satellite and terrestrial carriers anticipate regulatory approval and good technical performance for DBS-R (Weber 1991, 110:1). However, the business risk of ad-supported business means that independent financing would require a much higher rate of return than 8 percent and, therefore, higher audience acquisition costs. Over a 20-year time horizon, the return of this business would improve significantly because the second satellite launched would start with the revenue level generated after the first 10 years.

Assuming a 1997 start date, this analysis indicates that the value of revenue produced by a DBS venture could exceed $500 million by 2001 and $1.2 billion by 2006. However, these figures are contingent on achieving an audience of more than 80 million listeners in 6 years. This presumes very inexpensive receivers: $50 as a maximum.

Experience in Japan, where DBS-R is nearer to implementation, raises an issue about receiver pricing. Broadcasters want to force equipment prices to the lowest possible level, to acquire listeners quickly. Electronics companies want to maximize profit by balancing volume and margin objectives. This potential conflict of interest has resulted in debate and uncertainty about equipment pricing in Japan (Miyazawa 1992).

Advertising-supported DBS-R would need to penetrate the audience for morning and evening "drive times," which are key revenue generators. However, it is likely that car receiver sales will be paced by replacement of the domestic automobile fleet because they represent significant consumer investments. Cooperation with automakers or car rental companies could, therefore, provide significant opportunities to influence audience growth rates. Because the segment of the audience with the highest income tends to replace its cars more frequently, a focus on car radios could actually increase the recruiting efficiency of the station. The DBS-R audience would have a higher proportion of an attractive market segment: high-income listeners with newer cars.

Figure 6-22 modifies some key assumptions to represent the case of a subscription-based service. Fixed investment is assumed to be equal to the advertising-based service, along with audience acquisition and operating costs. Figure 6-22 alters the primary revenue relationships, however:

- Each listener pays a monthly charge of $3.00 for each channel he or she chooses to access.

- Listeners select three channels, on average.

- No broadcast advertising is sold.

The first two assumptions are made to keep subscriptions cost competitive with planned cable radio ventures. For example, Digital Planet radio is testing its residential service with a price of $8.00 per month and is recommending that cable companies charge less than $10.00. Of the 26 channels offered by Digital Planet, an individual listener is expected to find three to five suitable channels (Hock 1991, 12:9). By comparison, three channels for $3.00 each would cost a DBS-R subscriber $9.00 per month.

FIGURE 6-22
DBS-R Cashflow Analysis Subscription-Based Service
(Dollars in Millions)

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Audience (millions)	.0	.7	1.6	2.1	2.2	2.3	2.4	2.5	2.6	2.7
Subscription Revenue	0	74	176	232	241	251	261	271	282	293
Satellite Investment	230	330								
Audience Acquisition	15	20	10							
Receiver Development	10									
Initial Outlay	255	350	10	0	0	0	0	0	0	0
Expenses										
Programming	27	27	27	27	27	27	27	27	27	27
Ad Sales	22	22	22	22	22	22	22	22	22	22
General & Admin	36	36	36	36	36	36	36	36	36	36
Techical	5	5	5	5	5	5	5	5	5	5
Operating Cost	90	90	90	90	90	90	90	90	90	90
Pretax Cashflow	-345	-366	76	142	151	161	171	181	192	203
Taxes	0	0	0	0	0	0	35	73	77	81
Cashflow	-345	-366	76	142	151	161	136	108	115	122
Internal Rate of Return	8%									
ASSUMPTIONS										
Acquisition $/listener	$21.90	(2 spots/day for 1 year @ $15 CPM / 50% take rate)								
Listener Growth	4%	(without promotion)								
Monthly Charge/Channel	$3.00									
DBS-R CPM	3									
Hours/Week	126									
Spots/Hour	10									
Spot Sellout Rate		0%	0%	0%	0%	0%	0%	0%	0%	0%
Program $ per Channel	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
Ad Sales $ per Channel	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
G&A per channel	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Technical $ per Channel	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
Number of Channels	30									

Source: Booz·Allen analysis

L-404.6-23

The third assumption is consistent with the positioning strategy of DBS-R ventures. Listeners prefer their high-quality audio without commercials.

Under these assumptions, the audience required to achieve a minimal return of 8 percent is far smaller than that required for an advertising-based service: just 2.7 million listeners in year 10. Audience acquisition cost is correspondingly low—about 2 percent of the expenditure required for a service supported by advertising. The venture begins to make a profit in the third year. Business risk is far lower because of the smaller scale initial outlay. Under the assumptions of figure 6-22, DBS-R revenue will have a value of $241 million in 2001 and $293 million in 2006 if the business is launched in 1997.

Competitive capture is less of an issue for a subscription DBS-R service. The business described in figure 6-22 is essentially a niche market for a new service. Pay radio and advertiser-supported radio draw on two different sources of revenue; therefore, direct competition between the two is impossible. From the standpoint of the terrestrial radio industry, however, pay radio poses a threat because it may reduce the audience for terrestrial radio.

Cable radio may compete directly with DBS-R in some residential markets, but a DBS-R provider could promote the service to exploit its nationwide presence and commercial identity.

6.3 MOBILE SERVICES

As described in previous sections, the Mobile Satellite Services market can be segmented into market niches: voice, data, paging, and positioning services. Since digital and voice services can be and are carried on a variety of media and systems, the ability of satellite service providers to penetrate these market segments depends in large measure on how effectively satellites can satisfy service requirements. Criteria for determining the appropriate media to provide the service are developed in the following section.

6.3.1 Media Selection Criteria

When assessing a transmission medium for suitability to support a service, 10 factors come into play:

- Cost: includes the cost of transmission medium, ancillary cost of additional hardware and software, and potential expansion

- Capacity: speed of medium driven by response time (transmission time and processing time) and aggregate data rate

- Availability: medium available when needed (architecture, reliability) with sufficient carrying capacity to handle the volume of data (peak traffic)

- Expandability: ability to expand the scope of communication configuration (adding more devices or services at a location and/or adding more locations)

- Mobility: how mobile the user can be while using the medium

- Error rate: how susceptible the medium is to noise (natural or man-made) and signal distortion (a function of design and architecture)

- Security: the ability to prevent unauthorized users from accessing proprietary information, applicability of secure access protocols, encryption, and data propagation control

- Distance: geographical distances, isolation, and numbers of users to be served at distant or remote ends

- Environment: prohibitive international, national, regional, or local ordinances; prohibitive locales or leases; electrical or magnetic interference potential

- Maintenance: potential impact of medium failures, down-time duration, backup or contingency availability.

In addition to these criteria, there are application criteria—unique organizational applications (hardware characteristics such as speed, security, and availability) that drive medium selection.

Cost is a powerful factor favoring mobile satellite services. Satellite benefits from one key economy of scale: increasing returns to *geographic* scale. Space segment investment provides a fixed amount of capacity that can generate revenue from any user in the footprint of the satellite or satellites. By contrast, terrestrial mobile service systems must distribute cell sites throughout a service area. Depending on the shape of the terrestrial carrier's territory, the number of cell sites required can increase as the square of the maximum distance between users.

Survey data from the Cellular Telephone Industry Association suggest that cellular telephone capital investment depends primarily on two factors: the number of subscribers served and the number of cell sites (Leibowitz 1990, 8). A Booz·Allen regression analysis indicates that cell sites and subscribers together account for 99.8 percent of the variation in the cellular telephone industry investment data ($r^2 = .998$).

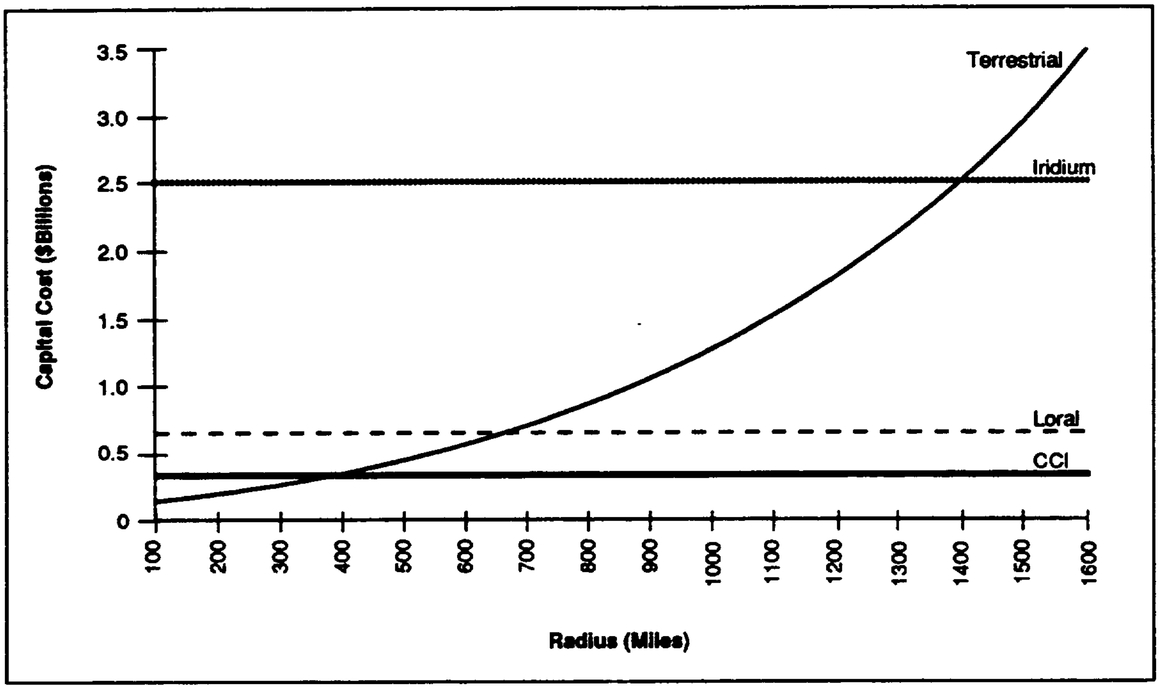
The form of the regression equation is as follows:

7. Investment $= 99.1 \times 10^6 + 405 \times (\text{subscribers}) + 7.08 \times 10^5 \times (\text{cell sites})$.

Terrestrial mobile telephone investment thus is composed of a component that can be directly associated with each subscriber, a component for each incremental cell site, and a substantial fixed cost component. Costs increase both with the number of subscribers and with the area of the territory covered. The $99.1 million "zero intercept" is not an initial cost that must precede installation—it represents significant expenditures that do not vary with changing numbers of subscribers or cell sites.

By contrast, satellite costs are constant with respect to geographical area up to the limits of the satellite footprints. By expressing equation 7 above in terms of cost per unit area, it is possible to compare satellite and terrestrial systems for territories of different size. For larger territories, satellite investment is more efficient, and this investment efficiency can support a competitive strategy of cost leadership.

FIGURE 6-23
Investment Crossover Points



Source: Booz·Allen analysis

Several assumptions are necessary to derive an equation for investment per unit area. Unit area per cell site is 7,850 square miles under the assumption that all cell sites have a 50-mile range. This assumption probably understates terrestrial capital requirements, because many cell sites have lower power or suboptimal local conditions. To account for the fact that cells must overlap, cell area is rounded down to 7,500 square miles. Customers per unit area will also affect terrestrial cellular investment. The average U.S. population density of 70 per square mile and average penetration of 1.1 percent indicate that each square mile of new territory requires investment in capacity for an average of .77 subscribers. Dividing the cost per cell site by the number of square miles served gives cell site cost per square mile: $94. Multiplying the cost per subscriber by the number of subscribers per square mile gives the subscriber cost per square mile: $312. The result is equation 8 below:

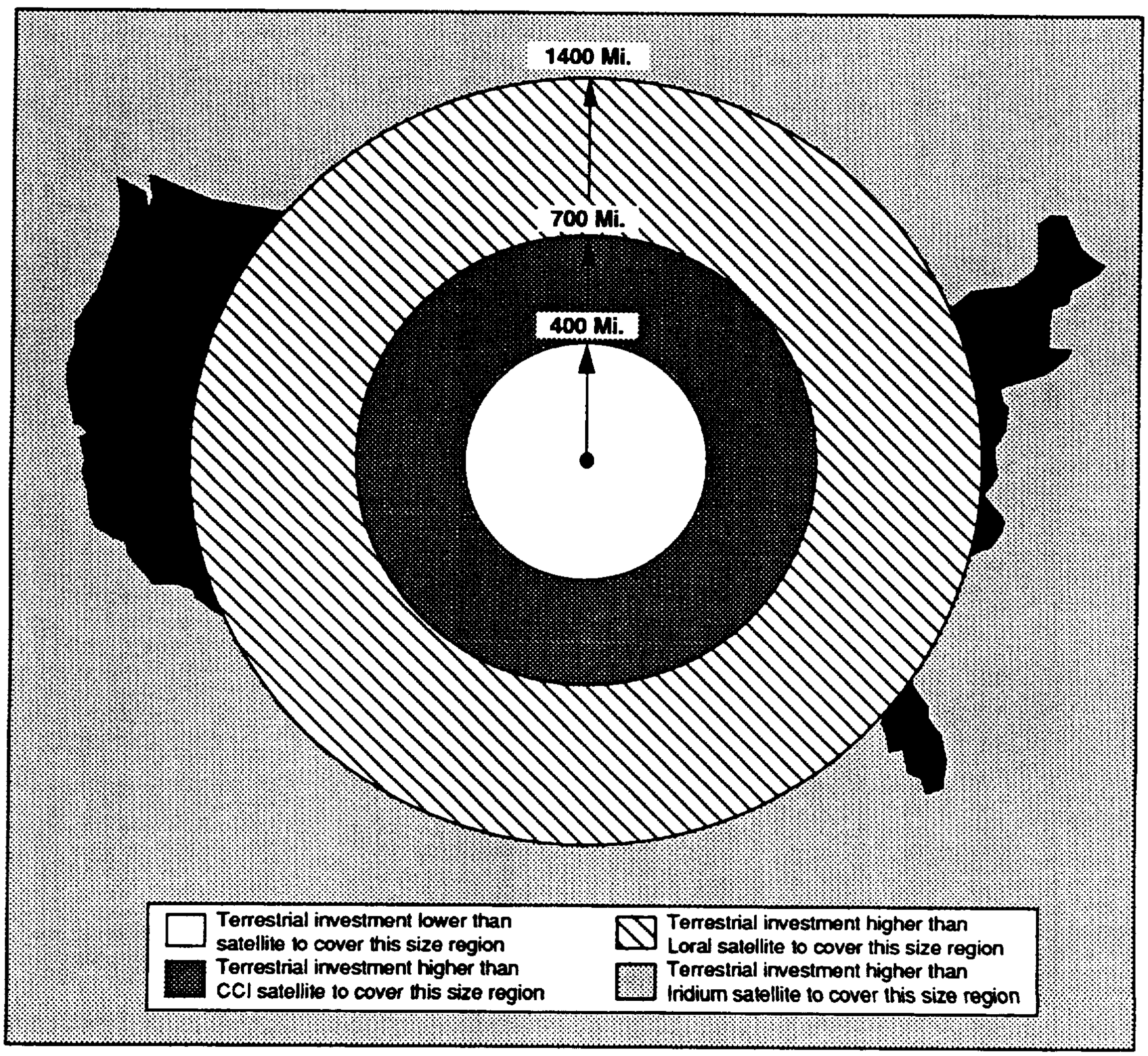
8. Investment $= 99.1 \times 10^6 + 406 \times$ (square miles).

Figure 6-23 displays terrestrial investment per mile to the projected cost of three different satellite systems. If terrestrial systems serve a circular territory comparable to a satellite footprint, satellite investment can be less if the territory radius is only 400 miles. Even Iridium, the most complex and expensive system envisioned, requires less investment than a terrestrial system covering a 1,400 mile radius. Figure 6-24 illustrates the areas for which various satellite systems have advantages in investment efficiency over terrestrial cellular. It should be pointed out that there is a simplification in equations 7 and 8 that implicitly makes satellite economics look more favorable than terrestrial. The numbers used to derive equation 7 are based on construction costs for urban cellular systems. For rural areas, with their lower traffic requirements, other approaches that cost less per square mile (although probably more per subscriber) would lower the average cost per square mile of covering the whole nation and therefore make terrestrial look more favorable compared to satellite than it does in figures 6-23 and 6-24.

Terrestrial systems can reduce capital requirements because they are not limited to covering a convex area. For example, an interstate right-of-way contains a high density of mobile service users in a minimal area. Terrestrial radio has greater flexibility to conform its investment patterns to population concentrations, "skimming the cream" of the market. The minimal service area is a linear pattern: for example, coverage of interstate routes.

For mobile service users, however, travel into an unserved area makes the system useless. Even if satellite is not the lowest cost solution, it can provide an important performance advantage to users: greater service flexibility with respect to subscriber mobility. Isolated or remote users can also be more efficiently served, making satellite more attractive with respect to the distance criterion.

FIGURE 6-24
Satellite System Scale Economies



Source: Booz·Allen analysis

FIGURE 6-25
Transmission Media Comparison

Technology	Fiber Optics	Wire Lines	Cellular	LOS Radio	Microwave	BLOS Radio	Satellite
Capacity	10 Mb/s - 2.4 Gb/s	T1 or less	120 analog voice channels per cell	5 or 25 kHz channels	1.544 Mb/s - 135 Mb/s	< 500 kb/s	Multi-T1
Topology	Primarily point-to-point	Point-to-point	Point-to-point, some multi-point	Point-to-point, multi-point, broadcast	Point-to-point, some multi-point	Point-to-point, multi-point, broadcast	Point-to-point, multi-point, broadcast
Availability	Good	Excellent	Good	Poor-Fair	Good	Fair	Good
Entry Barriers	Moderate to high	Low	Moderate to high	Low	Low to moderate	Low	Low as carrier service, very high for private nets
Cost/Use Trends	Usage up, cost down	Usage stable, cost stable	Both up somewhat	Usage stable, cost stable	Usage up, cost stable	Usage stable, cost stable	Both up somewhat
Security	Excellent	Requires encryption	Low	Requires encryption	Low; good with encryption	Low; good with encryption	Requires encryption
Expandability	Fair-good	Good	Fair-good	Excellent	Good	Good	Fair
Error Rate	Excellent	Fair-good	Poor	Poor	Fair	Poor	Good
Distant Users	Good	Poor-fair	Poor	Fair	Fair	Fair	Excellent
Environment	Good	Fair-good	Fair	Fair	Fair	Fair	Good

Source: Booz·Allen & Hamilton

Figure 6-25 compares seven types of transmission media against several of the media selection criteria given above. Fiber optic and cable/wireline systems are primarily point-to-point transmission media. The ubiquitous wireline systems have formed the backbone of the PSN local loop since the 19th century, while fiber growth has been phenomenal over the last 10 years, with fiber to the home (FTTH) soon to be a reality in the United States. Main disadvantages of this transmission mode include inability to have multipoint or broadcast connectivity, and high capital expense of initially wiring together large numbers of geographically dispersed users.

Line-of-sight (LOS) and beyond LOS (BLOS) media include microwave and other RF systems. One advantage LOS and BLOS radio systems have over fiber/wire systems is the ability to do multipoint and broadcast transmissions, an important feature when dealing with fleets of trucks or groups of pagers, for example. Unfortunately, channel noise and atmospheric conditions severely limit the useful range of RF systems to regional and/or local usage for most applications.

Cellular telephone and terrestrial LOS radio systems, including HF, VHF, and UHF, will be the main competitors to satellites for MSS services for local and regional users. On a national or international scale, however, the LOS limitation will restrict competition to GEO and LEO satellite systems. In other words, GEO and LEO satellite systems can be expected to capture nearly all of the global voice, data, positioning, and paging markets.

For true global coverage, limited only by the location of gateway earth stations, satellites offer the most viable solution. A satellite in geostationary orbit can cover about 42 percent of the earth's surface, meaning a system of three satellites in 22,300-mile orbits can cover the globe with point-to-point, multipoint, or broadcast signals. By using spot beam antennas, power controls, and advanced signal processing techniques, such as SSMA and CDMA, satellites can deliver high quality digital signals to the remotest areas of the globe. Suitability of satellites for global voice, data, positioning, and paging services is quite high, but satellites will have a tough time competing with terrestrial paging systems on cost.

6.3.2 MSS Application Areas

For purposes of this analysis, we will use four broad user areas as defined in section 4 of this document:

- Voice: a global, cellular-like service providing PSN connectivity to isolated or remote users
- Data: worldwide, computer-to-computer or facsimile connectivity
- Positioning: global geolocation and position reporting
- Paging: worldwide alphanumeric paging services.

Each application area is rated against the media selection criteria in figure 6-26. Each of the media selection criteria is ranked on a scale from 1 to 5, with 1 meaning the criterion is not very important to users and 5 being very important. For example, global positioning users (i.e., fleet operators) are less cost sensitive than pager users, who have more (terrestrial) options available to them for paging services.

FIGURE 6-26
Importance of Criteria for Mobile Service Applications

	Voice	Data	Positioning	Paging
Cost	3	3	1	5
Capacity	3	5	3	1
Availability	5	3	2	1
Expandability	5	4	3	2
Mobility	5	5	5	5
Error Rate	5	4	2	1
Security	3	3	1	1
Distance	3	3	5	3
Environment	5	3	2	2
Maintenance	5	3	2	1

Key: Very Important 5 4 3 2 1 Not Important

Source: Booz·Allen analysis

FIGURE 6-27
Ratings of Transmission Media

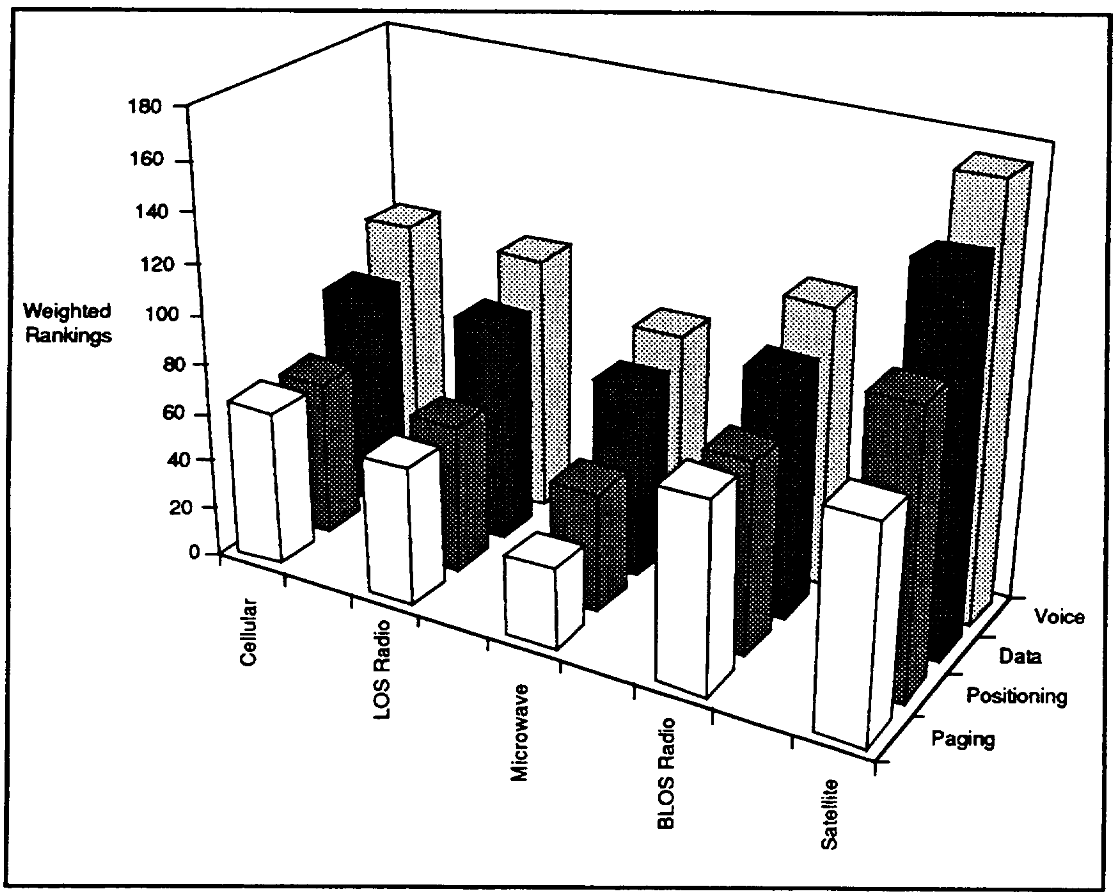
	Cellular	LOS Radio	Microwave	BLOS Radio	Satellite
Cost	4	3	1	5	2
Capacity	1	2	4	1	5
Availability	4	2	4	2	4
Expandability	4	5	3	5	4
Mobility	4	1	1	4	5
Error Rate	1	2	3	1	4
Security	1	2	3	1	4
Distance	1	2	2	4	5
Environment	2	3	2	2	4
Maintenance	2	1	2	2	4

Key: Favorable 5 4 3 2 1 Unfavorable

In figure 6-27, each of the candidate media for MSS services is ranked against the technology criteria from 1 to 5, with 5 representing an element where that medium may have a favorable advantage in that element. For example, LOS radio systems have a cost advantage since it is relatively cheap to add new users simply by buying more mobile transceivers at $300 to $1,000 each. On the other hand, microwave towers and transceivers would be expensive to install for each user, especially mobile systems.

By multiplying the media and applications rankings, comparisons can be made as to how each communications technology stacks up against the others when compared against users' requirements in each of the MSS application areas. Figure 6-28 depicts the weighted rankings. As one would expect, SATCOM can expect to capture most, if not all, of the global MSS markets in voice, data, positioning, and paging. It is worth noting that if the distance requirement is reduced, then cellular and terrestrial radio systems are strong competitors with GEO and LEO satellites for MSS traffic.

FIGURE 6-28
MSS Application/Media Comparison



Source: Booz·Allen analysis

6.4 TRAFFIC

Section 5 identified satellite-adressable traffic for specific services. This section estimates the satellite-capturable proportion of addressable traffic based on the results of the analyses in sections 6.1 through 6.3 of traffic in the areas of VSAT, DBS (TV and radio), and MSS.

Mesh VSAT. Figure 6-29 is based on the following competitive assumption about mesh VSAT traffic: Booz·Allen anticipates that terrestrial carriers will provide little mesh VSAT service, preferring to exploit the latent capacity of their installed fiber optics. Mesh VSAT services will be provided primarily by established satellite carriers or industry entrants. Capture by these satellite-oriented firms will be approximately the same in all categories because of trends toward integrated services and multiuse satellites. Capture increases from 0 percent in 1991 to 5 percent in 2001. From 1997 to 2006, capture increases slowly due to cost advantages, and rapidly in areas not served by BISDN, leveling off at 10 percent. Mesh VSAT never attains the 50 percent share that is capturable based on cost. This is because pricing and marketing plans can maximize profit by targeting a share too small to trigger tariff cuts by terrestrial carriers.

Mesh VSAT—Integrated Video Use. Figure 6-30 illustrates additional revenues that mesh VSAT can capture by 2001. This chart represents remote users of integrated video. This service adds 5 percent of mesh VSAT revenues by 2011.

FIGURE 6-29
Mesh VSAT Traffic Volume and Value

DS0s	Busy Hour DS0s				
	1991	1996	2001	2006	2011
Data					
Facsimile	0	0	1,800	880	1,150
E-Mail	0	0	950	7,400	12,000
Terminal Operations	0	0	730	2,100	3,000
On-Line Info. Services	-	-	-	-	-
EFT	0	0	25	59	61
EDI	0	0	35	80	83
Video					
Network Broadcast	-	-	-	-	-
Cable TV	-	-	-	-	-
Educational TV	-	-	220	830	1,400
Business TV	0	0	5,300	10,500	7,800
Viewer Choice TV	-	-	-	-	-
Total Traffic	0	0	9,100	22,000	25,000
Total Value ($ 000)	0	0	$ 56,000	$ 135,000	$ 155,000
% Mesh VSAT Capturable	0	0	5	10	10

Source: Booz·Allen analysis

FIGURE 6-30
Integrated Video Volume and Value

DS0s	Busy Hour DS0s 1991	1996	2001	2006	2011
Video					
Network Broadcast	-	-	-	-	-
Cable TV	-	-	-	-	-
Educational TV	0	0	130	140	140
Business TV	0	0	530	950	1,150
Viewer Choice TV		-	-	-	-
Total Traffic	0	0	660	1,100	1,300
Total Value ($ 000)	0	0	$4,100	$6,800	$8,000
100% Satellite Capturable					

Source: Booz·Allen analysis

Mesh VSAT—Remote Broadband Services. Satellite-based user-to-network services such as those described in section 6.1.3 can capture 1 percent of broadband services by targeting users without high-capacity terrestrial access. As described in figure 6-31, this should generate $410 million by 2011.

FIGURE 6-31
Remote Broadband Services

	Busy Hour DS0s 1991	1996	2001	2006	2011
Traffic Summary					
Frame Relay	32	1,350	290	195	190
SMDS	-	165	350	950	920
BISDN	-	-	3,500	23,000	64,000
Total	32	1,500	4,100	24,000	65,000
Value Summary					
Frame Relay ($ 000)	200	8,300	1,800	1,200	1,150
SMDS ($ 000)	-	1,000	2,200	5,900	5,700
BISDN ($ 000)	-		22,000	140,000	400,000
Total ($ 000)	$200	$9,300	$26,000	$145,000	$410,000

NOTE: 1 Percent of traffic to remote sites per figures 5-3, 5-4, and 5-5.
Source: Booz·Allen analysis

Mobile Satellite Services. Booz·Allen estimates that by the year 2000, satellite services could capture 20 percent of the 8-million users that Donaldson, Lufkin, and Jenrette believe will be without coverage from terrestrial services (Leibowitz 1990). Satellite MSS could also capture as much as 10 percent of the 30- to 40-million potential service users with unusual mobility requirements. Revenue and traffic depend strongly on whether mobile services complement or substitute for stationary wireline services. For this reason, Booz·Allen does not project mobile service traffic; however, 5.1 million users (1.6 million unserved by cellular plus 10 percent of 35 million) are a reasonable estimate of capture potential. A user base of 5.1 million is consistent with domestic satellite service revenues of $6.1 billion in 1990 dollars, given the $100 per month mobile services cost cited by Donaldson, Lufkin and Jenrette (Liebowitz 1990, 30).

Direct Broadcast Satellite. DBS traffic volume is strongly dependent on the positioning strategy of individual service providers and is unrelated to revenue. For this reason, section 6.2 concentrates on the competitive viability of DBS business. DBS, especially DBS-R, is likely to coexist with other delivery modes throughout the latter portion of the forecast horizon.

6.5 CROSS IMPACTS

Section 4 of this study examined seven applications:

- Frame relay
- SMDS
- BISDN
- Mesh VSAT
- DBS
- Mobile services
- Integrated video.

Section 6 identifies markets capturable by satellite implementations of these applications. It examines mesh VSAT, DBS, and satellite-based mobile services. Because mesh VSAT can address needs served by frame relay, SMDS, and integrated video, these three applications cover satellite's role in all of the major applications identified in section 4.

The following discussion identifies the cross impacts among the seven terrestrial- and satellite-based applications listed above. Figure 6-32 displays the cross impacts in matrix format.

Each row and column of figure 6-32 is labeled with one of the seven applications. Each cell corresponds to the effect of one application on another. Certain cells have an arrow pointing upward or an arrow pointing downward. The downward arrow indicates a relationship in which an increase in usage of one application reduces use of the other. The upward arrow indicates a situation in which increasing usage of one application promotes another. The downward arrow represents a substitution relationship: each application is an alternative to the other. The upward arrow represents a complementary relationship: use of one service increases the effectiveness or utility of the other, or one service is a necessary adjunct to another.

In the top row of figure 6-32, frame relay shows its impact on SMDS, BISDN, and mesh VSAT. The substitution relationships among frame relay, SMDS, and BISDN are graphically summarized in figure 4-3. More use of frame relay would most likely arise from the deferral of the more advanced broadband services, perhaps because frame relay becomes accepted as a standard and vendors enhance it with additional features. For this reason, use of frame relay is negatively related to SMDS and BISDN, as shown by the downward-pointing arrows. Frame relay is also a partial substitute for mesh VSAT because lower-rate data traffic can be carried among closed user communities on either application.

FIGURE 6-32
Cross-Impacts

	Frame Relay	SMDS	BISDN	Mesh VSAT	DBS	Mobile Services	Integrated Video
Frame Relay		↓	↓	↓			
SMDS	↓		↓	↓			
BISDN	↓	↓		↓	↓	↑	↑
Mesh VSAT	↓	↓	↓				
DBS			↓				
Mobile Services			↑				
Integrated Video			↑	↑			

Source: Booz·Allen analysis L-404.6-24

The second row of figure 6-32 displays a similar set of substitution relationships. As SMDS use increases, SMDS will supplant near-term use of frame relay. Conversely, BISDN will supplant SMDS in the later years of the forecast horizon. Mesh VSAT is a partial substitute for SMDS; therefore, greater acceptance of SMDS implies a lower market share for mesh VSAT. Downward arrows indicate these relationships.

The third row shows the eventual effect of BISDN on other applications. BISDN, as the most advanced and versatile application, has significant effects on all other applications. BISDN will be a highly competitive alternative to frame relay, SMDS, and mesh VSAT. Availability of BISDN's advanced features and high bandwidth will lead to replacement of frame relay and SMDS applications. The versatility of BISDN may reduce the prospective market for mesh VSAT systems after the year 2000.

The third row also shows that increased use of BISDN will have an inverse effect on DBS use. The substitution relationship here depends on whether regulators will permit LECs to offer

VOD. It also depends on the rate at which LECs replace residential local loops with fiber optic cable. If residential subscriber lines can support video and if LECs are permitted to provide it, BISDN can offer video service that is more convenient than any of its alternatives. VOD will capture a significant amount of the revenue from price-insensitive market segments.

BISDN is complementary to two applications: mobile services and integrated video. The availability of BISDN may promote use of mobile data services, and the high and variable bandwidth of BISDN will probably promote acceptance of integrated video by cutting costs and increasing transparency.

The fourth row shows the substitution relationships between mesh VSAT and terrestrial broadband services. Greater commercial success by mesh VSAT services will reduce terrestrial carriers' shares of traffic among closed user communities. The fifth row indicates that wide acceptance of DBS may limit the role of BISDN in home video delivery, which many LECs are counting on as the most reliable source of future revenue growth. Row six shows that mobile data services may increase domestic traffic, boosting demand for BISDN. This effect is not shown for the other broadband services because it will take time for mobile data innovations to gain acceptance and mature. BISDN will probably be the primary application by the time mobile data are a significant source of demand, and thus will be the primary beneficiary of any new mobile data traffic. The seventh row shows that user acceptance of integrated video will stimulate demand for B-ISDN, because BISDN is the application best suited to video transmission for an open user community. Increased acceptance of integrated video will also stimulate demand for mesh VSAT capacity, particularly if mesh VSAT is less expensive than terrestrial transmission. The beneficial effect of integrated video will probably decline in importance in the later years of the forecast horizon. The diminished impact of integrated video will result from increasingly ubiquitous video terminals. As more people acquire video terminals, video users will benefit most from transmission that does not restrict them to a closed user community.

7.0 CONCLUSIONS

7.1 GENERAL COMMUNICATIONS TRAFFIC TYPES, VOLUME, AND TRENDS

Demand for telecommunications capacity is the result of a huge, slowly growing base of voice traffic coexisting with video and data services, some of which will grow at a much faster rate.

MTS will be of continuing but decreasing importance. MTS, the largest component of domestic traffic, has recently grown at 12 percent per year, but this high rate reflects factors that will diminish during the forecast horizon. Telecommunications deregulation in the 1980's eliminated the practice of subsidizing local calls with higher long-distance charges. Deregulation also promoted price competition. The MTS market is approaching saturation as the effect of these one-time factors abates. Over the 1991 to 2011 forecast horizon, future growth will average 7 percent per year.

Booz·Allen anticipates that private lines will undergo price competition to offset loss of traffic to virtual private networks. However, pricing will not fully offset losses as virtual private networks evolve into a substitute for private lines. The result will be negative private line growth after 2000, and a compound annual unit growth rate of less than 1 percent during the forecast horizon. This will be a net result of 4 to 5 percent growth until 2001, followed by an offsetting decline. Virtual private networks will grow at 7 percent.

The 800 service traffic will grow slightly faster than its recent trends would indicate. Unified national signaling and database systems will offset the near-term effects of a slow economy, which will induce limited substitution of 900 lines for customer service and sales. Growth will begin to slow until 2000, as mild market saturation sets in. The net effect of these factors will be 7 percent compound annual growth from 1991 through 2011.

Caller-paid inbound services, or 900 services, have suffered from abuses and the consequent threat of regulation. As these short-term effects abate, significant growth will ensue when 900 services cut prices to position themselves as substitutes for some 800 offerings. Annual growth is expected to average 7 percent during the 1991 to 2011 forecast horizon.

Multiple generations of fax machines are in use. This will shorten life cycles and make changing growth rates an evident effect of innovation diffusion and market saturation. Price competition, penetration of residential markets, and new features made possible by ISDN compatibility will offset and defer saturation of current markets. However, improved compression and the emergence of electronic mail as a fax substitute will greatly reduce the capacity demands of the growing installed base of fax terminals. The net effect will be an 81 percent decline in fax traffic in the course of the 1991 to 2011 forecast horizon.

Electronic mail is likely to be the most dynamic component of data traffic. Electronic mail will evolve into a nearly ubiquitous service (160 million users), driven by increasing interconnectivity among applications and software-based directories. Frequency of use will increase during the forecast horizon, and messages size will increase as data services are integrated. An explosive annual growth averaging 84 percent will result.

Computer terminal operations are the background against which specific data services are projected. Computer terminal operations will grow by almost 12 percent annually from 1991 through 2011 as computer processing becomes more distributed and interconnections proliferate.

In this study, Booz·Allen does not project the growth of imaging transmissions, which will grow rapidly from a minimal base. Imaging traffic growth depends strongly on the progress of integration with other types of data and with advances in storage and retrieval technologies.

On-line information services will grow by 22 percent annually through 2011, although faster potential growth will be retarded by human factors and concomitant lack of integration into work and consumption patterns. The more specialized services offered by research networks have shown explosive growth recently, but their growth has been confined to military and academic users, along with individual users in corporations. We do not project research network growth, because it depends strongly on the extent to which commercial ventures transform existing networks into services that meet a broader range of needs.

EFT transactions for interbank and consumer transactions will increase to more than six times their current level from 1991 to 2011. Interstate banking and proliferation of point-of-sale terminals will drive this growth, along with moderate consumer acceptance of paperless transactions. EFT traffic and channel requirements will grow at a compound annual rate of 10 percent.

The growth of EDI will be retarded in the near term because local exchange carriers are prohibited from providing value-added services. Other near-term inhibiting factors include prospective users' security concerns and lack of knowledge of the benefits of EDI. As these problems are addressed, technological advances will cause growth to accelerate sharply through 2000. Sustained rapid growth would require significant changes to computer architectures, which are unlikely to be evident until after 2011. From 1991 through 2011, EDI will average 9 percent annual growth.

Capacity for network broadcasters will grow more slowly than requirements for data services. Compression technology and availability of fiber optic capacity for point-to-point transmission will tend to accelerate channel growth by reducing transmission cost. The advent of HDTV and viewer-choice television will also stimulate demand for additional channels. However, competition from cable and other video delivery systems will moderate this growth somewhat. The chief effect will be 57 percent greater efficiency in bandwidth use due to improved compression. The net effect will cause required network broadcast video capacity to decline by 50 percent in 20 years. By contrast, cable channels will average relatively constant annual growth of just under 5 percent. Cable broadcasters' response to competition from local exchange carriers will be to segment their programming for more specific interests and to serve their audience with more channels. Transmission economies accruing from video compression advances will result in a 30 percent decline in transmission requirements.

Educational television growth depends on technological advances that cut cost and on user acceptance, which has been cautious to date. The net effect of increasing user acceptance and compression efficiencies will be a 39 percent decline in bandwidth demand during the forecast horizon.

Business TV growth is an amalgam of services penetrating the corporate market at different rates. Services are differentiated by image quality: full-motion video (45 Mb/s) will grow relatively slowly because of its cost, while the growth of limited motion video (56 to 384 kb/s) will be constrained by its lower quality. Limited full-motion video (384 kb/s to 2.048 Mb/s) will exhibit the highest traffic growth in the next 15 years because compression technology will offer users an improved tradeoff between cost and performance. From 1991 to 2001, the average 12.7 percent per year increase in daily conference-hours is more than compensated for by decrease in bandwidth requirements due to compression, resulting in a net two-thirds reduction in bandwidth demand. From 2001 to 2011, the annual increase in daily conference-hours of 1.4 percent per year combines with a shift toward higher-picture-quality services to result in an annual increase of 2.7 percent in bandwidth demand.

It is too early to develop meaningful projections for the long-distance transmission component of Viewer Choice TV because of unresolved business and cost issues (see section 2.5.5). Using many assumptions, an example shows that it could develop into the second largest consumer of interLATA bandwidth by 2011. Growth and volume will be negligible until 2000, at which time regulatory restrictions and local loop constraints will have been removed and business relationships will have been established. After 2000, VCTV could grow at 16 percent per year.

7.2 TELECOMMUNICATIONS INFRASTRUCTURE STATUS AND PLANS

Today, after years of conversion from coaxial cable and microwave by interexchange carriers, long-distance phone service in the United States is primarily carried on single-mode optical fiber, with only a few carriers maintaining digital microwave communications in areas with rough terrain or low population density. Conversion to fiber began in 1983, with fiber installation proceeding rapidly. The rapid installation was a result of the 1982 AT&T divestiture agreement, which intensified competition among interexchange carriers on the basis of capacity and quality. For competitive reasons, long-distance carriers began installing fiber in their networks and marketing their services as providing connections with clarity and quality superior to older technologies. This competitive environment resulted in significant capital expenditures (more than $5 billion as of 1986) by nine of the nation's leading long-distance companies to provide long-distance fiber communications. By 1987, the bulk of the long-distance phone service had been converted to fiber. Today, Sprint, with its 23,000-mile all-fiber network, provides long-distance service that has been entirely fiber since 1988. MCI reported that as of 1990 its domestic network was 99% digital and targeted at 100 percent by February 1992. Most of MCI's network is fiber, with digital radio remaining in some locations. As of 1988, AT&T had more than 23,000 fiber route miles in place and was planning to lay an additional 10,000 miles by 1993. By December 1991, AT&T had installed 31,400 of its planned 33,000 fiber route miles. AT&T plans an entirely digital network by 1993, with only a small fraction of the digital microwave radio remaining. Other interexchange carriers, such as WilTel, RCI Long Distance, ATC, Consolidated Network Inc., Mutual Signal Corporation, Communications Transmission Inc., and Norlight, accounted for an additional 22,000 fiber route miles across the country by 1988.

Local exchange carriers began installing fiber around 1987, the same time as long-distance carriers began to slow their investments. The Department of Commerce estimated that the Bell Operating Companies deployed about 1.5 million miles of fiber by the end of 1988. These lines connect the carrier to the IEC networks and interconnect LEC central offices. Today, the LECs have virtually completed their interconnection plans.

Even with all the expansion by the IECs and LECs, the use of fiber has been almost completely confined to interoffice trunking. Penetration into the local loop, where traffic volume is lower, distances are shorter, and costs per subscriber line have been high (presently around $1,600), has been slow. Because of the cost, LECs are not expected to begin major installation of fiber in the local loop until around 1995.

Several issues are now pressing the cable TV industry toward fiber networks. Due to the lifting of government restrictions against LECs providing information services, the major network broadcast corporations (NBC, ABC, and CBS) are investigating with the IECs the transmission of network programming over their fiber networks. This move could pave the way for the high-bandwidth transmission necessary for HDTV. When the LECs have installed their fiber networks and with permission from the Government, it would be possible to receive network programming over fiber optic local loops. These issues are creating an environment that is driving the cable TV industry toward the use of fiber optics in their networks.

The use of Ku-band satellites is continuing to grow because of the attractive cost advantages of VSAT systems using higher-powered Ku-band transmissions. The number of Ku-band transponders in orbit will nearly double the number of C-band transponders by the mid to late 1990s [3]. GTE Spacenet Vice President David Fiske forecasts that Ku-band video transponder use will equal C-band use around 1995.

The change from C-band to other bands, however, will occur slowly. Several top satellite service providers, including Hughes Communications and GE American Communications, are committed to continued services extending through this century. According to Hughes, more than 15,000 commercial C-band installations exist at cable headends, television stations, and other businesses around the country. More than 90 percent of all domestic television stations have a C-band satellite capability. This represents a significant investment in C-band terrestrial plant, ensuring continuing C-band use. There are estimated to be nearly 3 million privately owned C-band backyard satellite dish installations. Despite a major decline in sales of home TVRO equipment caused by the scrambling of cable programming services, there still exists a significant user base to keep the C-band market viable throughout this century.

A number of new satellites carry both C-band and Ku-band transponders, permitting the implementation of networks that take advantage of the characteristics of both frequency bands. Nonetheless, the number of satellites recently launched, planned, or in construction shows an unmistakable move toward Ku-band as the dominant satellite delivery technology in the near future.

Recently the FCC granted authority for Norris Satellite Communications, Inc. to proceed with construction, launch, and operation of the first U.S. commercial telecommuncations satellite operating at Ka-band (30/20 GHz). The experimental NASA ACTS satellite, which operates at Ka-band, is scheduled to be launched in 1993.

The main driver behind the interest in LEO satellite systems is interest in the cellular telephone, fax, and voice messaging businesses. Recent estimates are that, as international economic integration progresses, the number of subscribers to mobile services could reach 100 million worldwide by 2000.

Unlike terrestrial cellular systems, in which users move though adjoining "cells" or areas of coverage, mobile satellite systems would beam a moving cell onto the surface of the earth. LEO satellites would be able to provide cellular phone service to a wide area without the delays associated with GEO systems.

Motorola Corporation in 1990 announced plans to develop a global cellular network called Iridium. This system will provide worldwide point-to-point communciations. It will provide telephone service, facsimile, data transmission, global paging, RDSS, and GPS for millions of users. The system will be based on the deployment of 66 small satellites positioned in 6 low-altitude polar orbits with 11 satellites in each plane.

Fiber optics offers almost infinite bandwidth and transmits data with virtually no errors. Fiber began to dominate the long-haul telecommunications traffic during the 1980's. The microwave market not addressed by fiber optics was being challenged by satellites. For example, during the 1980's much of the cable and broadcast TV market that had used microwave systems migrated to satellite transmission. The increased use of fiber optics and satellites has drastically reduced the use of long-haul microwave transmissions. There are still microwave systems in use, but most applications that were historically based on microwave technology have been or will be converted to other transmission media.

Significant expansion of short-haul microwave technology is expected in the future. Several new technologies, including cellular and personal communication networks, will spark new growth in the microwave industry. Short-haul microwave serves as a complement to fiber optics and is therefore not in direct competition. Because of short-haul's advantages and advancements in technologies, it has not experienced the same loss in market share as long-haul microwave. Short-haul microwave technology should continue to experience growth with the advent of new applications that fit into its market niche.

7.3 APPLICATIONS

Applications expected to dominate use of the communications infrastructure through the year 2011 that are examined in this report include: broadband technologies, fixed satellite systems, integrated video, and mobile satellite systems. We project with a high degree of confidence that these applications will be technically feasible and economically viable within the time horizon of this study. Additionally, we expect each of these applications to account for a significant amount of traffic generated. Status, plans, deployment coverage, cost, and traffic projections are examined for each application presented.

Broadband Technologies

Emerging high-speed data transmission requirements, a changing ratio of voice to data traffic, and the emergence of increased video traffic are spurring the development of advanced technologies to support anticipated demand for broadband communication services. Common to all these new services is the rapid development of efficient packet technology as the basis for new network architectures to support these services. Packet technology is replacing circuit technology because of the benefits it brings to rapidly growing end-user applications such as LAN interconnection.

Three emerging broadband services analyzed in this report are frame relay, SMDS, and BISDN. Although available today, frame relay and SMDS have been included in this study because their deployment and user acceptance over the next several years will serve as indicators of demand for broadband services. Over time, we expect to see frame relay eventually migrating onto BISDN as a bearer service, and SMDS serving as an access technology for BISDN.

Frame Relay

Frame relay is an emerging data access standard that is being used to interface private network backbone switches and is also being offered as a carrier-based service. It is based on a variable-length packet structure and is capable of supporting data applications at transmission speeds up to 2.048 Mb/s. More than 50 manufacturers have announce plans to develop products that support frame relay and more than 19 carriers have plans to offer frame relay services.

The most likely scenario for the deployment of frame relay over the next 5 years is a hybrid approach in which traffic will pass between private and public networks. Hybrid networks will reduce leased-line costs for users by allowing them to connect their private networks to public networks by using packetized facilities such as ATM. Also, the hybrid approach will provide users with significantly greater flexibility in configuring and reconfiguring their networks, resulting in further cost savings.

Demand for frame relay services will primarily be driven by the demand for high-speed LAN-to-LAN interconnects. We expect frame relay applications to account for a significant amount of data transmission traffic until cell-based transmission technology such as ATM becomes widely available. Frame relay traffic is expected to experience rapid growth through 2000, when some of this traffic will migrate onto BISDN where available and some will migrate to higher-bandwidth alternatives such as SMDS.

SMDS

Bellcore developed SMDS as a carrier service concept for connectionless data service. It is intended to provide a high-speed, central office-based metropolitan area network that will give users an alternative to private systems. The primary application for connectionless data transfer is for high-speed (DS-1 or DS-3) LAN-interconnect type service. While frame relay can support both connection-oriented and connectionless data transfer at lower transmission rates, SMDS is more narrowly focused to support only connectionless data transfer at significantly higher rates.

SMDS, having both DS-1 and DS-3 access rates, will be attractive to both large- and small-to-medium-sized businesses if priced competitively. Initial interest in the service will focus on the DS-1 access rate and will be deployed to customers already having facilities that can support this transmission rate. Over time, larger business customers will migrate towards the DS-3 access rate to meet higher-speed LAN interconnect requirements. Emerging technologies such as high bit-rate digital subscriber line (HDSL) will allow the economical upgrade of the existing copper plant to support the DS-1 access rate and will place SMDS within the reach of small-to-medium-sized businesses.

Demand for SMDS will be driven by the need for LAN-to-LAN interconnects that can support higher speed data transfer than is available with other technologies such as frame relay. As LAN speeds increase to rates of 16 Mb/s for token rings and 100 Mb/s for FDDI, high-speed

LAN-interconnect services such as SMDS will be essential to support the trend towards distributed processing over greater distances. We expect to see rapid growth of SMDS traffic through the year 2000 and a slowing of growth as SMDS lines are upgraded to support ATM and are used as access links for BISDN or supplanted by BISDN for new service applications.

BISDN

BISDN represents the next major step in the evolution of the public switched telephone network. It is intended to support a host of interactive and distribution services ranging from voice to high-quality video. Based on an infrastructure of optical fiber transmission and fast-packet switching systems, BISDN can reduce the need for service-specific networks, thereby reducing overall network operation costs. BISDN is intended to extend the integration provided by ISDN within the loop plant to include the switching, signaling, and transport facilities to support broadband services.

All major local exchange and interexchange carriers are aggressively prosecuting plans to upgrade their networks to support broadband service offerings. Generally, networks are being upgraded in two phases: expansion of SONET-based fiber optic transmission facilities and upgrade of the switching fabric to include ATM capabilities. Local exchange carriers are deploying various fiber-to-the-curb and fiber-to-the-home systems to support extension of broadband transmission capabilities to the customer premise. Carriers are planning to deploy broadband switching capabilities to support large business customer applications first, then gradually achieve widespread upgrade of their switching fabric to support small business and residential customers.

Despite the inherent advantages of a universal BISDN, development and investment costs associated with deploying such a network on a large-scale basis are prohibitive in the short term. Therefore, a major technical challenge that faces the communications industry is to allow the time-phased implementation of BISDN. The industry consensus is that the migration strategy will include four phases: deployment of broadband transmission capabilities to the customer, introduction of BISDN services, integration of MANs into BISDN, and the introduction of television distribution via BISDN.

While a point-to-point application such as BISDN is not cost-effective for the major part of TV broadcasting (point-to-multipoint), there are many TV distribution applications for which BISDN is suitable. Examples are program collection (news, features, previously-recorded shows) and downloading of video to VOD "jukeboxes." These are non-real-time applications. Even real-time transmission need not present an insuperable problem: the maximum delay can be bounded with a very high probability; together with the very low price of memory, one can consider downloading with only very slight transmission delay. For entertainment purposes, an occasional missed frame that is interpolated by the decompression logic would not be noticeable.

Demand for services supported by BISDN can be analyzed as two major segments, business and residential. Business services will be characterized by high-bit-rate connectionless data transfer to support the growing demand for information retrieval and transfer among computers, and variable-bit-rate services to support rapid growth in image traffic. Residential services will be focused on providing entertainment programming and convenience services such as in-home shopping and banking. Business applications will account for initial BISDN traffic in the 1998 time frame with traffic continuing to grow as existing services are migrated to BISDN and additional capabilities are introduced. As carriers continue to deploy fiber optic transmission systems in the loop, broadband services will be made available to a growing number of residential customers beginning around the year 2000, and reaching widespread availability by the year 2011.

VSAT

VSAT networks are an alternative to terrestrial-based networks for primarily closed user group applications. These networks can be configured for full-duplex transmission, as in interactive networks, or simplex transmission, as in one-way data broadcast networks, depending upon specific user applications. In addition to traditional VSAT networks that employ a large hub earth station, mesh VSAT networks are emerging as an alternative solution to a variety of new customer networking requirements. Advantages of VSAT networks include the capability to provide economical private communications with a high degree of reliability, serve geographically dispersed locations, and support easy reconfiguration or network expansion.

Mesh VSAT networks can be based on two approaches: enhanced terminals using traditional satellites equipped with standard "bent-pipe transponders," or advanced next-generation satellites equipped with on-board switching capabilities. One manufacturer, Spar Communications, is offering a mesh VSAT system that does not require satellites equipped with on-board switching capabilities. This type of mesh VSAT allows communication among terminals without a hub station by distributing intelligence normally located at the hub to the terminal stations. NASA's ACTS program is pursuing development of a next-generation communication satellite that will have on-board switching capabilities and will support mesh VSAT networks.

Due to the closed user group limitations and the relatively high cost of mesh VSATs, VSAT and mesh VSAT systems will be best suited to customized applications. These applications will be primarily data transmission including, facsimile, e-mail, terminal operations, EFT, and EDI. Additionally, video traffic generated by educational and business television will continue to be VSAT applications.

DBS

DBS is a term used to describe a satellite delivery system designed to provide video, audio, and data services directly to the end-user. One distinguishing characteristic of DBS is the relatively high power of the broadcast signal, which allows the use of relatively small receiving antennas. Currently, the U.S. has no "high-powered" DBS systems in operation. Eleven applications are on file with the FCC for video systems and four are on file for audio systems. Additionally, there have been several inquiries into the viability of using DBS for other types of service delivery including data services, news services, and educational programming. Although these applications indicate a high degree of industry interest, it is extremely unlikely that all the DBS proposals before the FCC will reach the operational stage.

In the DBS video arena, Hughes' DirecTV will be the first operational DBS system in the U.S. with a launch date scheduled for December 1993. The Hughes system will provide direct broadcast television to the coterminous U.S. with an initial programming package of approximately 20 channels, similar to those provided on cable television. None of the other DBS applicants have progressed to the point where concrete plans exist and launch dates have been scheduled.

Integrated Video

The component technologies of video telecommunications have been evolving for more than 25 years without achieving widespread user acceptance. Since 1980, two important trends have improved the prospects for this application: improvements in video coding have resulted in better image quality at lower bandwidth and, largely due to VLSI, equipment prices have declined significantly. Additionally, usage-sensitive costs such as transmission costs have dropped significantly due to competitive pressures and the introduction of fractional T1 services.

Industry activity focuses on developing desktop or personal video systems capable of using POTS lines for transmission. Designers for equipment suppliers feel that the compression level of codecs for POTS has reached the limit imposed by low POTS transmission rates, and more bandwidth will drive quality improvements through the year 2000. For example, image quality improvements could be made possible as a result of the increased bandwidth available using ISDN.

The primary factor affecting the volume of integrated video traffic is the integration of voice and data services. ISDN will be a critical factor in promoting the growth of integrated video. Industry projections are that full feature video telephony based on the ISDN multi-use bearer group will be available in 1995. This means that both video conferencing and video telephony will be technically able to provide integrated video features. However, video telephony will concentrate for the near term on low bandwidth to capture residential and business markets that rely on POTS rather than ISDN.

MSS

Mobile satellite systems are designed to deliver a range of communication services to a wide variety of terminal types. Mobile satellite terminal platforms include land vehicles, aircraft, marine vessels, and remote data collection and control sites. Portable terminals used for these services are briefcase size, but may be reduced to handheld sizes for future systems. Basic mobile services supported by these systems include voice, data, paging, and position determination. Systems can also be configured to provide services among a closed user group, such as a government agency or company, with satellite communications being provided between mobile terminals and a base station.

A variety of service providers are emerging in response to growing demand for mobile satellite services to support land, aeronautical-, and sea-based applications. Inmarsat and Qualcomm are providing service in the U.S., demonstrating the economic viability of these systems. However, most potential commercial mobile satellite service providers' systems are in the planning stages with filings before the FCC. Service providers have expressed a wide variety of spectrum requirements for mobile satellite systems ranging from 1 MHz to 220 MHz of bandwidth in L-, S-, C-, Ku-, and Ka-bands. Additionally, a variety of concepts have been proposed for these systems, ranging from the use of new or existing geostationary satellites to systems based on low- or medium-altitude satellites.

The industry consensus is that MSS will experience rapid market growth over the time horizon of this study. As people become more reliant on telephone systems for voice and data connectivity, they are also demanding greater freedom from the fixed-plant wireline systems.

MSS will serve markets without cellular service coverage and offers the potential to greatly enhance productivity for a variety of business and mobile office applications.

7.4 SATELLITE-ADDRESSABLE MARKETS

Among the applications that will dominate the nation's infrastructure to 2011, several could be served by satellite technology. To identify feasible satellite implementations of these dominant applications, we analyzed each application along three interrelated dimensions: technical adequacy, competitiveness, and user acceptance. The application groups that we found to have significant potential for satellite addressability are broadband services, VSAT, direct broadcast satellite, and mobile satellite services. Integrated video was not of sufficient volume to be satellite addressable independent from other applications. However, integrated video, as an end-user application, is possible through satellite enhancement of BISDN or through VSAT, and is therefore handled as a subset of those sections.

Technical adequacy refers to the ability of a technology or service to meet the technical communication requirements of an application. Competitiveness is defined in this analysis as the potential of a technology to become a substitute for other means of providing a communication service. Competitiveness also identifies the competing technologies and the level of competition among companies in the industry segment being examined as well as among those companies in other segments that will provide competing technological solutions. User acceptance has both an objective and a subjective component. Although some segments of satellite technology have aesthetic considerations that limit or hinder user acceptance, such as restrictions placed by communities on the installation of earth stations (objective), most issues of user acceptance deal with the product's quality of transmission and ease of use to determine the product's subjective utility to the consumer. Cost has an indirect effect on the level of user acceptance by affecting the perceived utility of the application.

Each application group, as defined in section 4, is segregated into types of traffic that are expected to be major consumers of infrastructure in the next 20 years.[1] The major types of traffic are voice, data, and video; each is evaluated on its constituent traffic elements. Based on the results of analysis, each traffic type is given a weight reflecting the overall addressability of the application and applied to the total traffic estimates for each type to derive the quantity of traffic that can be addressed.

Broadband ISDN

Broadband services provide the capability to move vast amounts of data on the order of hundreds of megabytes in a matter of seconds. These services will be provided by frame relay, SMDS, and BISDN. Presently there are no satellites capable of providing these services, but the potential exists for these applications to become a major portion of total national traffic.

The need for high bandwidth data transmission will increase in the future because of the increased transmission of image data and of megabyte file transfers between supercomputer networks. Both of these data types exist within a closed user community. For instance, T1 speeds are already commonly used for LAN-to-LAN interconnection and for backbone transmission in

[1] See section 2, General Communications Types, Volumes, and Trends for a complete list and description of the traffic types.

large research networks such as NSFNET. Point-to-point video is also a potentially large user of BISDN services.

From a technical standpoint, BISDN can be adequately transmitted via satellite, but the competition from terrestrial carriers will be intense. The most attractive niche for satellite enhancement of BISDN will be to closed networks of remote users. User acceptance will be greater for traffic that is not affected by the 250-millisecond transmission delay for geosynchronous communications.

Mesh- and Star-Connected VSAT

Present satellites are not capable of supporting mesh-connected VSATs with bit rates greater than 1.544 Mb/s. However, future satellites may incorporate high-power spot beams and switching capabilities, thereby allowing manufacturers to develop less expensive mesh VSAT terminals. The significant installed base indicates that technical adequacy of VSATs has been achieved. Yet the competitive pressures faced by VSAT, whether star- or mesh-configured, from other terrestrial means of providing a communications path will be such that prices of terminal equipment and airtime must continue to decline. User acceptance is particularly strong for VSATs, especially mesh, because VSATs are capable of providing high-quality transmission for data, video, and, with some constraints, voice with great reliability and sometimes with quicker response times than is possible with terrestrial circuits.

Direct Broadcast Satellite

Because DBS is by definition satellite addressable from a technical standpoint, the most important issues focus on competitiveness and user acceptance. Competition in the market in which DBS will participate is already very strong. Significant barriers to entry that must be overcome for DBS to be successful include procuring a license to operate, distributing DBS terminals, and securing an adequate supply of programming. Because the cable franchises already have a very strong foothold in the urban markets, DBS will have the greatest chance of success by filling the unmet needs of the approximately 30 million homes that are not presently passed by cable. In this market, DBS will compete only with a subset of audio and video delivery modes. Present technology makes TVRO a very expensive investment for most users because of the required large receiving dish, whereas DBS, with its greater signal strength, allows the use of 18-inch-diameter dishes. In addition, DBS will have a competitive advantage over both cable and terrestrial television broadcast because of its potential to deliver HDTV-quality progamming to a mass audience much sooner. The overall higher quality of DBS signals, whether it is HDTV to urban subscribers or NTSC to rural subscribers, is a strong factor in favor of long-term user acceptance.

Mobile Satellite Services

Satellites can address needs for four specific mobile services: voice, data, positioning, and paging. On the basis of overall user utility, satellite is the most attractive medium for each of these services. Satellites have unique advantages in market segments requiring global or broad regional coverage. If users need service only over limited distances, terrestrial radio has significant cost advantages, particularly in the paging market. But for voice, data, and positioning, satellites can offset lower terrestrial costs with higher capacity and lower bit error rates.

7.5 SATELLITE CAPTURABLE MARKETS

Mesh VSAT can address the need for lower data rates (less than 45 Mb/s) supplied by broadband services applications. Mesh VSAT can also provide integrated video functionality. The most promising VSAT market is for private networks (i.e., closed user communities).

The results of Booz·Allen's analysis indicate that the private network market can be divided into segments according to two characteristics of the private network's user community: size and geographic dispersion. The number of users affects VSAT cost per node because more users can share transponder or hub costs among a larger number of terminals. Geographic dispersion affects the cost of nodes in private line networks because longer links cost more.

Comparative cost structures for conventional (hub and spoke) VSAT and terrestrial private lines have changed in favor of VSAT since 1989. In 1989, VSAT was more economical for networks of 400 terminals or more as long as users were located more than 225 miles apart. Even with smaller distances between users, larger networks can compensate for shorter and cheaper terrestrial links. When users average 100 miles apart, VSAT is less expensive if 2,800 terminals are linked.

Under assumptions that network size has a skewed distribution and network dispersion is uniformly distributed, conventional VSAT technology was the low-cost solution for an appreciable fraction of networks with fewer than 3,000 nodes.

- Forty-eight percent of users are capturable by VSAT networks competing with private line networks averaging 6 drops per line, if a 7-year evaluation period is used.

- Fourteen percent of the market is capturable if prospective users compare VSAT to private networks with 6 drops per line over a 5-year period.

- Thirty percent of the market is capturable from private line networks with 12 drops per line, if users evaluate investments over a 7-year period.

Under 1992 pricing, conventional VSAT is cost competitive for private networks with more than 300 users, even when the distance between terminals is as low as 25 miles. When the average dispersion of the user community puts terminals an average of 50 miles apart, VSAT networks with 200 terminals are less expensive than terrestrial alternatives.

This situation permits VSAT-based technologies to provide a lower cost alternative to private line networks composing 75 percent of the private network market. We can predict with confidence that 75 percent of users would now choose satellite over other alternatives if cost were the sole consideration. Of course, cost competitiveness is not the only factor affecting market share. Before VSAT could approach a 75 percent market share, other factors would likely constrain its penetration, such as a competitive response by terrestrial carriers.

The potentially capturable shares listed above are shares of the total market, but they exclude networks with more than 3,000 users and networks with terminals separated by more than 325 miles. It is likely that VSAT can be a competitive solution for these larger and more dispersed networks.

From 1989 to 1992, the competitive cost position of VSAT has improved markedly, primarily because of lower earth station cost. For three reasons, however, cost-competitiveness must be qualified to constitute a complete gauge of VSAT's business potential. First, terrestrial carriers could compete more aggressively on price. Firms, at least the non-dominant common carriers, would probably price more aggressively if they judged the risk of VSAT competition to be greater than the risk of disrupting the industry's relatively stable and predictable pricing policies. Second, terrestrial carriers have significant noncost competitive advantages: for example, high existing market share and entrenched customer service and sales networks. And third, long-distance telecommunications firms have recently succeeded in de-emphasizing price competition. The effect of these changes is to increase the importance of the carriers' ability to tailor solutions to user needs. Competitive conditions have undoubtedly slowed the diffusion of satellite innovations, resulting in market shares much lower than satellite could capture based solely on cost.

Mesh VSAT systems are under commercial development. Mesh VSAT is not yet ready for widespread commercial use, but technological advances are likely to make this solution cost-competitive within the forecast horizon of this study.

With a 1992 pricing structure, mesh VSAT is not cost-competitive. Mesh VSAT terminals usually assume some hub functions, leading to increases in their cost. Current vendor estimates are approximately $50,000 per terminal. Although hub costs are considerably reduced, this does not offset the increased cost per user relative to conventional VSAT systems.

If mesh VSAT earth station prices decline as rapidly as conventional VSAT in the near term, mesh VSAT is not cost-competitive for networks with fewer than 3,000 user sites until 1998. But in 1998, a substantial fraction of the most dispersed networks come within reach. Networks with 200 nodes are cost-effective mesh VSAT applications if users average 175 miles apart. VSAT may be cost-competitive if users average just 125 miles apart. In 1 year, the market share that mesh VSAT can capture on a cost basis jumps from almost 0 to more than 50 percent. If VSAT earth station cost declined more slowly, by 20 percent per year, in 1998 a mesh VSAT solution would be more costly for networks with fewer than 3,000 users. By 1999, only 21 percent of the market would be capturable.

Under the conservative assumption of 20 percent annual earth station cost reduction, Booz·Allen believes that by 1999, 21 percent of users will definitely choose mesh VSAT over other alternatives if cost is the sole consideration.

Just as in the terrestrial VSAT market, market penetration will lag its full potential because the innovation must diffuse through the user community. The private network market will have significant factors that will retard acceptance of mesh VSAT innovations, whether it is using terrestrial or satellite networks. Terrestrial network users will have established relationships with competing suppliers. Satellite network users may also have inhibiting influences—for example, significant investment in conventional VSAT systems.

It is likely that after 1998, price declines will moderate while mesh VSAT systems diffuse through an increasing percentage of the capturable market. Mesh VSAT will not necessarily cannibalize business from hub and spoke systems, however. Hub and spoke architectures are likely to remain attractive for applications with data that principally flow to or from a central point.

Broadcasting and Direct Broadcast Satellite

DBS technology can be used to broadcast audio or video. Broadcasting markets have different characteristics than private network telecommunications markets. Competitive viability in broadcast markets results not from traffic-based revenues but from charges to users or advertisers. For this reason, the competitive position of broadcast media is unrelated to the number of user channels. Competitive position depends on the revenue that can be generated from the content of a limited number of channels. Also, in the consumer market for broadcast entertainment, subjective criteria play an important role by comparison with the VSAT market.

Video DBS competes with broadcast television, cable, videocassettes, and theaters. In the future, video DBS may also have to compete against video on-demand supplied by local exchange carriers. A notional consumer choice model indicates that DBS is the least attractive delivery mode for price sensitive market segments. DBS is likely to be more attractive than theaters to segments where convenience is more important because DBS offers home access and greater selection convenience.

Although DBS is rated less attractive than most competing delivery modes, this does not mean that it will not be chosen by consumers. All of the four currently prevalent services—cable, television, theaters, and video stores—coexist in most areas. Individual viewers often use several services because services occupy niches defined by program content or novelty, and because viewers' strength of preference for program content and convenience changes continually.

One obvious niche for DBS is based on location. Areas where some alternatives are distant or unavailable are more likely to adopt and use DBS. For example, the 12 percent (as of 1990) of homes not passed by cable are a natural market. Areas with poor television reception have long been natural DBS niches, particularly if they are remote. Areas with low population density handicap services like video stores and theaters that do not offer home access. In the future, the single most ubiquitous competitor to DBS will probably be LEC video on-demand offerings, which are are potentially available to all telephone subscribers.

The relative attractiveness of DBS increases dramatically, to second or third place from fourth or sixth place (see figures 6-19 and 6-20), if earth station prices fall into the $100 to $200 range.

HDTV technology has the potential to make image quality an important factor distinguishing different delivery modes. Adoption of a digital HDTV standard could give DBS an important competitive advantage. DBS could be the first medium to broadcast HDTV using digital decoders that could interchangeably display HDTV and conventional resolution TV. This would differentiate DBS from its terrestrial competitors and improve its competitive position. It may then be possible to price DBS services higher than other video offerings.

DBS-R has characteristics that are very different from those of the existing terrestrial radio broadcast industry. One important attribute is that a different receiver is required. Another important attribute is that satellite is inherently suited to a national, or at least regional, audience. A third key DBS-R attribute is that it can offer a large number of channels, up to 100 in some configurations.

We conclude that sufficient penetration of the national radio audience can support the capital expenditure of a DBS-R satellite, whether the system is supported by advertising or by subscription. The advertising CPM (cost per thousand listeners) of DBS-R can compete with terrestrial radio rates because the higher capital cost can be offset by greater reach.

Assuming a 1997 start date, this analysis indicates that the value of revenue produced by a DBS venture could exceed $500 million by 2001 and $1.2 billion by 2006. However, these figures are contingent on achieving an audience of more than 80 million listeners in 6 years. This presumes very inexpensive receivers and audience acquisition costs that dwarf the cost of space segment investment. Consequently, advertising supported DBS-R would be a very risky proposition, particularly in the near term because of competitive conditions in the terrestrial industry.

A subscription-based service could achieve an equivalent return with a far smaller audience than that required for an advertising-based service: just 2.7 million listeners in year 10. Total audience acquisition cost is correspondingly low, about 2 percent of the expenditure required for a service supported by advertising. The venture could begin to make a profit in the third year. The business risk of a subscription service is far lower because of the smaller scale initial outlay. In this case, DBS-R revenue could have a value of $241 million in 2001 and $293 million in 2006 if the business were launched in 1997.

Competitive capture is less of an issue for a subscription DBS-R service. Satellite pay radio is essentially a niche market for a new service. Pay radio and advertiser-supported radio draw on two different sources of revenue, so direct competition between the two is impossible. From the standpoint of the terrestrial radio industry, however, pay radio poses a threat, because it may reduce the audience for terrestrial radio.

Satellite provision of mobile services has strong potential, due to its superior performance and significant economies of scale. Booz·Allen analysis rated satellite higher overall than any other medium that could be used to supply cellular services. Key satellite performance advantages include flexibility to accommodate highly mobile and distant users. The most important satellite cost advantage is the ability to cover larger areas with minimal incremental investment. This scale economy makes satellites less capital-intensive for service areas as small as 30 miles in radius. Booz·Allen projects that mobile satellite will capture a preponderance of the addressable market.

Cross-impacts among terrestrial and satellite-based applications result from substitution potential or complementarity. More use of frame relay would mean deferred adoption of the more advanced broadband services, perhaps because frame relay becomes accepted as a standard and vendors enhance it with additional features. For this reason, use of frame relay is negatively related to SMDS, BISDN, and mesh VSAT, because lower rate data traffic can be carried among closed user communities on either application.

Similar inverse relationships link other broadband technologies. As SMDS use increases, SMDS will supplant near-term use of frame relay. Conversely, BISDN will supplant SMDS in the later years of the forecast horizon. Mesh VSAT is a partial substitute for SMDS; therefore, greater acceptance of SMDS implies a lower market share for mesh VSAT.

As the most advanced and versatile application, BISDN has significant effects on all other applications. BISDN will be a highly competitive alternative to frame relay, SMDS, BISDN, and mesh VSAT. Availability of BISDN's advanced features and high bandwidth will lead to replacement of frame relay and SMDS applications. The versatility of BISDN may also reduce the prospective market for mesh VSAT systems after the year 2000.

Increased use of BISDN will also have an inverse effect on DBS use. The substitution relationship here depends on whether regulators will permit LECs to offer video on demand. It also depends on the rate at which LECs replace residential local loops with fiber optic cable. If residential subscriber lines can support video, and if LECs are permitted to provide it, BISDN can offer video service that is more convenient than any of its alternatives.

BISDN is complementary to two applications: mobile services and integrated video. The availability of BISDN may promote use of mobile data services. And the high and variable bandwidth of BISDN will probably promote acceptance of integrated video by cutting costs and increasing transparency.

Greater commercial success by mesh VSAT services will reduce terrestrial carriers' shares of broadband services traffic among closed user communities. Wide acceptance of DBS may limit the role of BISDN in home video delivery. Mobile data services may increase domestic traffic, boosting demand for BISDN. This effect will not be pronounced for the other broadband services because it will take time for mobile data innovations to gain acceptance and mature. BISDN will probably be the primary application by the time mobile data is a significant source of demand, and thus will be the primary beneficiary of any new mobile data traffic. User acceptance of integrated video will stimulate demand for BISDN, because BISDN is the application best suited to two-way video transmission for an open user community. Increased acceptance of integrated video will also stimulate demand for mesh VSAT capacity, particularly if mesh VSAT is less expensive than terrestrial transmission. Integrated video's stimulative effect on VSAT will probably decline in importance in the later years of the forecast horizon. Integrated video will no longer stimulate VSAT use when video terminals become sufficiently ubiquitous. As more people acquire video terminals, video users will benefit more from services that do not restrict them to a closed user community.

LIST OF ACRONYMS

ACTS	Advanced Communications Technology Satellite
ADSL	Asymmetric Digital Subscriber Line
AHP	Analytic Hierarchy Process
AMSC	American Mobile Satellite Corporation
ANS	Advanced Network and Services
ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
AT&T	American Telephone and Telegraph Co.
BBS	Bulletin Board System
BISDN	Broadband ISDN
BITNET	Because It's Time NET
BLOS	Beyond Line of Sight
BSB	British Satellite Broadcasting
BSS	Broadcast Satellite Service
CAD/CAM	Computer-Aided Design/Computer-Aided Manufacturing
CATV	Cable TV
CCI	Constellation Communications Inc.
CCITT	International Telegraph and Telephone Consultative Committee
CDMA	Code-Division Multiple Access
CIX	Commercial Internet Exchange
CO	Central Office
CONUS	Contiguous United States
CPD	Consumer Productivity Dividend
CPE	Customer Premise Equipment
CPM	Cost per Thousand
CPU	Central Processing Unit
CSNET	Computer + Science NET
CSU	Channel Service Unit
DAB	Digital Audio Broadcasting
DBS	Direct Broadcast Satellite
DBS-R	Direct Broadcast Satellite - Radio
DCT	Discrete Cosine Transform
DDS	Digital Data Service
DoD	Department of Defense
DSU	Data Service Unit
EDI	Electronic Data Interchange
EDIFACT	EDI for Administration, Commerce and Transportation
EFF	Electronic Frontier Foundation
EFT	Electronic Funds Transfer
EIE	Electronic Information Exchange

EIRP	Equivalent Isotropic Radiated Power
EMA	Electronic Mail Association
FCC	Federal Communications Commission
FDDI	Fiber Distributed Data Interface
FDMA	Frequency-Division Multiple Access
FT1	Fractional T1
FTTC	Fiber to the Curb
FTTH	Fiber to the Home
G&A	General and Administrative
GEO	Geosynchronous Earth Orbit
GPS	Global Positioning Service
GSA	General Services Administration
GSM	Groupe Speciale Mobiles
HBO	Home Box Office
HDSL	High-Bit-Rate Digital Subscriber Line
HDTV	High-Definition Television
IEC	Interexchange Carrier
IF	Intermediate Frequency
INWATS	Inward Wide-Area Telephone Service
IRR	Internal Rate of Return
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
IT&T	International Telephone and Telegraph Co.
IVHS	Intelligent Vehicles/Highway System
LAN	Local Area Network
LATA	Local Access and Transport Area
LEC	Local Exchange Carrier
LEO	Low Earth Orbit
LOS	Line of Sight
MAN	Metropolitan Area Network
MCU	Multipoint Control Unit
MFJ	Modified Final Judgment
MPEG	Motion Pictures Experts Group
MSS	Mobile Satellite Service
MTS	Message Telephone Service
MUB	Multi-Use Bearer Group
NAB	National Association of Broadcasters
NASA	National Aeronautics and Space Administration
NRTC	National Rural Telecommunications Cooperative

NSF	National Science Foundation
NSFNET	National Science Foundation NETwork
NTSC	National Television System Committee
NVOD	Near Video on Demand
OLIS	On-Line Information Services
O&M	Operations and Maintenance
PBX	Private Branch Exchange
PC	Personal Computer
PCN	Personal Communications Network
POS	Point of Sale
POTS	Plain Old Telephone Service
PPNS	Private Packet Network Service
PPV	Pay Per View
PSN	Public Switched Network
PVC	Private Virtual Circuit
RBOC	Regional Bell Operating Company
RDSS	Radio-Determination Satellite Service
RF	Radio Frequency
RSC	Radio Satellite Corporation
SDBN	Software-Defined Broadband Network
SLC	Subscriber Loop Carrier
SMDS	Switched Multimegabit Data Service
SNA	Systems Network Architecture
SNMP	Simple Network Management Protocol
SONET	Synchronous Optical Network
SS7	Signaling System 7
SSMA	Spread Spectrum Multiple Access
SVC	Switched Virtual Circuit
TDMA	Time-Division Multiple Access
TMI	Telesat Mobile Inc.
TVRO	Television Receive-Only
USSB	United States Satellite Broadcasting
VAN	Value-Added Network
VCR	Video Cassette Recorder
VCTV	Viewer-Controlled Cable Television
VITA	Volunteers in Technical Assistance
VLSI	Very Large-Scale Integration
VOD	Video On Demand
VSAT	Very Small Aperture Terminal

WAN	Wide-Area Network
WARC	World Administrative Radio Conference
WATS	Wide-Area Telephone Service
WDM	Wavelength-Division Multiplexing
XA-SMDS	Exchange Access SMDS

SECTION 2 REFERENCES

American Management Association. *EDI at Work*. 15-20.

Andrews, Edmund L. 19 August 1991. "The 'Baby Bells' as Godparents." *New York Times*. 140. C3(N). D3(L).

Armstrong, J. Scott. 1978. *Long-Range Forecasting*. John Wiley & Sons, New York

Association for Information and Image Management, Technology Group. 17 January 1992

AT&T. 1990. *The World's Telephones 1989–1990*. Morristown, NJ.

Barlow, J. P. January 1992. "The Great Work." *Communications of the ACM*. 35:25.

Barnes, C. October 1991. "On-line Information Systems." *1991 Falkner Technical Reports*. Pennsauken, NJ: Falkner Technical Reports Inc.

Baron, David, and Michael Shaughnessy. 16 December 1991. "Cable Television at the Crossroads." *Digital Media: A Seybold Report*. 1(7):5–9.

Blankenhorn, D. 13 September 1991a. "Telesphere Files for Bankruptcy, Leaves '900' Line Biz." *Newsbytes*.

Blankenhorn, D. 25 September 1991b. "Sprint Stops Billing for Most 900 Services." *Newsbytes*.

Booz·Allen & Hamilton report.

Boyd, John. 14–15 May 1992. "Video Dialtone." Presented at Telestrategies , Video Dial Tone–Protecting the Telco Base. Washington, D.C.

Briere, D. 19 June 1989. "The Numbers Game." *Network World*. 6:51–53.

Broitman, Robin, and Connie Kennedy. 14–15 May 1992. "Video-On-Demand Trials: The Jury is Still Out." Presentation at Telestrategies Conference Video Dial Tone—Protecting the Telco Base. Washington, D.C.

Burns, N. Spring 92. "Promises and Reality." *Interoperability*, a supplement to *LAN Magazine*. 28–33.

Caprioglio, Albert. Consultant, Communications Systems Development. Conference.

Callem, R.E. 9 September 1991. "Support: Reach Out and Charge Someone; Vendors Debate Merits of '900' Lines." *Computer Reseller News*. 437:S17–S18.

CBEMA Industry Marketing Statistics. 1988. *The Information Technology Industry Databook 1960–1998*. Washington, D.C. 142.

CBEMA Industry Marketing Statistics. 1990. *The Information Technology Industry Databook 1990*. Washington, D.C. 93–104.

CCMI, McGraw Hill. 1991. *CCMI Guide to Networking Services*. Vol.1, *InterLATA Telecommunications Rates and Services*. Rockville, MD: CCMI/McGraw Hill.

Champenu, S. J. "The 1991 900 Service Market at a Glance." *Network World*. New York: Strategic Telemedia.

Communication News. August 1990. System Dynamics. "Users' E-Mail Favorites."

Communications Week. 4 November 1991. "PC Mail Explosion."

Compression Labs. Telephone conversation.

Consumer Trends. 5 February 1990. "POS Networks Counted."

Contel Federal Systems. December 1989. *US Computer Research Networks: Current and Future*. Prepared for NASA Lewis Research Center. NASA Contract No. NAS3-25083. Cleveland, Ohio.

Contel Federal Systems. December 1990. *U.S. Computer Research Networks: Domestic and International Telecommunications Capacity Requirements*. Prepared for NASA Lewis Research Center. NASA Contract No. NA53-25083. Cleveland, Ohio.

Cope, P. 30 September 1991. "X.500 Shows Users the Way to the Future." *Network World* 32.

Data Communications. July 1989.

Data Communications. November 1991. "The Big Picture for H.261."

Datapro Information Services Group. January 1991. "Interstate Private Line Facilities: Market Overview." In *Data Networking — Leased Line Services* from Northern Business Information/Datapro Estimates. Delran, NJ: McGraw-Hill.

Datapro Information Services Group. March 1991. "Modems, Market Overview." Delran, NJ.

Datapro Research Group. August 1990. Datapro Management of Telecommunications. Delran, NJ.

Dataquest. 1989. *Dataquest Telecommunications Industry Service*. Vols. 1–3. San Jose, CA.

Dataquest. *May 1991. Market Statistics–Long Distance Telephone Services Marketplace*. San Jose, CA.

David, Bob. 10 April 1992. "FCC's Proposal for HDTV May Restrict Broadcasters." *Wall Street Journal*. B1(W). C1(E).

Edelstein, H. A. November 1991. "Imaging Shifts Emphasis to Workflow Management; Document Imaging Systems Promise Productivity, and Opportunity for 'Business Process Design.'" *Software Magazine*. 2:96-100.

EDGE On & About AT&T. 11 May 1992. "Visual Communications: AT&T Offers First End-to-End System to Cable TV Industry. 7(198):7.

The EDSAT Institute. 1991. *Analysis of a Proposal for an Education Satellite*. Washington, D.C.: The Edsat Institute.

Elbert. "Private Telecommunication Networks." *PC Week*.

Falkner Technical Reports Inc. January 1991. "AT&T Domestic Inbound Services." In *Falkner Technical Reports*. Pennsauken, NJ. 1-12.

Falkner Technical Reports. 1991. *Electronic Data Interchange*. Pennsauken, NJ: Falkner Technical Reports.

FCC, Industry Analysis Division. 24 September 1991a. *Long Distance Market Shares: Second Quarter, 1991*. Washington, D.C.

FCC. 24 September 1991b. *FCC Releases Report on Long Distance Market*. Washington, D.C.

FCC. 1990. *Statistics of Communication Common Carriers*. 1989/90 Edition. Washington, D.C.

GAO. February 1989. *Electronic Funds Transfer*. Washington, D.C.

Gildea, J. September 1991. "The Evolution of Computing Architectures. " *Booz-Allen & Hamilton Systems Source* 3.

Habegger, J. September 1991. "Why is the NREN Proposal So Complicated?" *Telecommunications*. 21- 26.

Heath, D. January 1991. "Virtual Networking/Telecommunications." *Telecommunications*. 25:25-30.

Herman, E. 2 December 1991. "Comparing '800' Service Guarantees - MCI Tries to Match AT&T with a Promise of 30-Minute Recovery." *Communications Week* . 25.

Information Hotline. April 1986. "Computer Postal Services Will Double Business By 1990; Electronic Mail To Overtake Telex Eventually." 16.

Information Hotline. May 1985. "Five-Year Growth in Online Data Bases Hits 500%." 17:1.

International Communications Research. Cable Profile Database.

International Resource Development Inc. April 1987. *Electronic Document Interchange Markets USS International*. Report 732.

International Resource Development Inc. October 1988. "*On-line Transaction Processing Markets --The Next Ten Years.* " Report 751. New Canaan, CT.

International Resource Development Inc. September 1989. *Electronic Mail In The 1990s*. Report 763. New Canaan, CT.

ITT, U.S. Telephone and Telegraph Corp. for NASA. 1979. *The 30/20 GHz Fixed Communications Systems Service Demand Assessment.* vol. 2, *Main Report.* Report No. CR 1159620. Cleveland, OH.

ITT, U.S. Telephone and Telegraph Corp. for NASA. May 1983. *Customer Premises Services Market Demand Assessment 1980–2000.* vol. 2, *Final Report.* Report No. CR 168151. Cleveland, OH.

Jenks, A. 9 April 1992a. "Making the Network Hum; Programs to Get Individuals Working Together. " *Washington Technology.* 27.

Jenks, A. 9 April 1992b. "And Now from Lotus, Discussion Databases." *Washington Technology.* 27.

Jenks, A. 23 January 1992c. "Viva Voice! E-Mail's Vocal Cousin Is on Crescendo of Popularity. " *Washington Technology* 31.

Kimberly, P. *Electronic Data Interchange.*

Magidson, S. May 1992. "Gaining a Handle on the Corporate Laptop User." *Network Computing.* 3:72.

Mallory, Jim. 30 April 1992. "Zenith TVs Will Soon Offer On-Screen Program Listings." *Newsbytes.*

Mason, Charles F. 10 February 1992. "Video Dial Tone Plan Pleases Few." *Telephony.* 222(6):11–12.

McCusker, T. 15 August 1991. "Soft-Switch Talks To Almost Everybody." *Datamation.* 33.

Messner, E. 12 August 1991. "Senate Committee OKs Bill Curbing 900 Service Abuses: Mandate Advertising, Billing Requirements. " *Network World.* 8:11-12.

Morgan, Ted, Ricoh. January 1992. Telephone interview.

National Cable TV Association. 4 January 1992. Telephone conversation.

Network World. 4 November 1991. "Major Study Mulls Future for E-Mail. " 6.

Network World. 18 May 1992. "Worth Noting." 13.

Office Products Analyst. March 1991. "Facsimile Market Overview."

Office Products Analyst. May 1986. "Facsimile Equipment."

The Official Westsat Satellite Communications Satellite Service Chart. January/February 1989.

POS News. September 1990. "Online and ACH Debit Growth is Steady." 3.
POS News. September 1990. "Online and ACH Debit Growth is Steady." 3.
Rosenberg, B. October 1987. "Money Machines Outgrow Banking." *High Technology Business* 37.

Rosenblatt, A. January 1992. "PCs and Workstations." *IEEE Spectrum*. 29:27–29.

Saunders, S., and P. Heywood. 21 May 1992. "X.400's Last Window of Opportunity." *Data Communications*. 74.

Schiff, Leonard. 14–15 MAY 1992. "Compressed Digital Video Transport." Presentation at Telestrategies conference. Washington, D.C.

Soft-Letter. 3 February 1990. " 900 Lines: A New Twist in Tech Support." 7:1–2.

Sullivan, Roger. Wang Laboratories. Private conversation.

Taff, A. 18 March 1991. "FCC Poses Rules to Regulate Provision of 900 Services." *Network World*. 8:68.

Telecommunications. February 1992. "US Sprint to Provide Commercialized Internet Service." 9.

Telecommunications. November 1991. "News Briefs – Bright Future For E-Mail." 20.

Telecommunications. August 1991. "Industry Outlook – E-mail: An Exponential Growth Curve." 15.

The Television Factbook. 1988.

U.S. Bureau of the Census and the Gartner Group. 1990. "Computers in the Office." *Statistical Abstract of the United States*. Washington, D.C.: U.S. Bureau of the Census. 943–953.

U.S. Bureau of the Census. 1990. "Households, Families, Married Couples, and Unrelated Individuals: 1960 to 1990." *Statistical Abstract of the United States* (Table No. 56) 45.

Western Union for NASA. August 1983. *Satellite Provided Fixed Communications Services: A Forecast Of Potential Demand Through The Year 2000, Final Report,* Vol. 2, *Main Text*. Report No. CR 168146. Cleveland, OH.

Wheelwright, S.C., and S. Makridakis. 1980. *Forecasting Methods for Management*, 3rd ed. New York: John Wiley & Sons. 5.

The Yankee Group. March 1988. *Electronic Mail Update*. Boston, MA.

Yankee Group. January 1991. "Private Lines Services: Winners and Losers." *Telecommunications*. Boston, MA. 25:16.

Zerbiec, T. G. January 1991. "Private Network Challenges and Opportunities for the 90's." *Telecommunications*. 25:33–36.

SECTION 3 REFERENCES

Business Communications Review. February 1991. "Planning for Broadband Services in Private Networking."

Caprioglio, Albert F. 9 December 1991. Private conversation.

Computergram International. 16 September 1991. "Intelsat Threatens Motorola's Global Phone System."

Congress of the United States, Office of Technology Assessment. January 1990. "Critical Connections: Communications for the Future."

Data Pro Reports on Communications Alternatives. August 1990.

Data Pro Reports on Telecommunications. August 1991.

FCC. "Statistics of Communications Common Carriers, 1989/1990 Edition."

Fiber Optics. January 1991. "Fiber to the Home Special."

Foley, Jim. October 1991. "Iridium: Key to Worldwide Cellular Communications." *Telecommunicating.* 25:23–28.

Forbes. 3 November 1986. "Optical Fiber Illusions."

IEEE Communications Magazine. November 1988. "Future Optical Fiber Transmission Technology Networks."

Kessler Marketing Intelligence. 1989. Map, "Fiber Optic Long Haul Systems Planned and in Place."

LAN Magazine. June 1987. "Fiber Cabling."

Network Management. November 1988. "The VSAT Network Finally Comes of Age."

Network World. 25 November 1991. AT&T Earmarks $3b for 1992 Network Upgrades.

Shumate, Paul W. Jr. February 1990. "Cost Projections for Fiber in the Loop." *IEEE LCS Magazine.*

Telecommunications Report. 29 June 1992. "Norris Authorized to Construct, Launch First Commercial U.S. Ka-band Telecom Satellite."

Telecommunications Transmission Handbook. Third edition 1991. Roger L. Freeman, John Weiley & Sons, Inc.

Telecommunications. August 1990. "Motorola Unveils Global Satellite-Based Cellular Network." 24:19–20.

Telephony. 2 July 1990. "Motorola Outlines Worldwide Cellular." 14.

Telephony. 18 September 1990. "How Fast is Technology Coming?"

Telephony. November 1990. "Telcos Park Fiber at the Curb." *Telephony's Transmission Special*. 8–10.

Telephony. November 1990. "Vendors Race to Bring Fiber into the Loop." *Telephony's Transmission Special*. 12–22.

Via Satellite. July 1990

Washington Technology. 7 November 1991. "Baby Bells Buy Way Into New Markets."

Washington Technology. 19 December 1991. "Iridium HQ Lands in DC Under Kinzie."

Kishimoto, R. August 1991. "HDTV Communication Systems in Broadband Communication Networks." *IEEE Communications Magazine*.

Korzeniowski, Paul. February 1991. "VSATs Come Down to Earth." *Communications Week*.

Krauss, Dr. Jeffery A. April 1991. "Satellite Communications: Legal and Regulatory Issues. *Datapro Reports on Communications Alternatives*.

Lodge, John H. November 1991. "Mobile Satellite Communications Systems: Toward Global Personal Communications." *IEEE Communications Magazine*.

Marek, Susan. August 1991. "1991 Private Networks Directory." *Satellite Communications*.

Marek, Susan. May 1990. "1990 Private Networks Directory." *Satellite Communications*.

Marek, Susan. August 1988. "1988 Private Networks Directory." *Satellite Communications*.

Marek, Susan. August 1987. "1987 Private Networks Directory." *Satellite Communications*.

Mazar, Robert A., and Kenneth A. Halverson. November 1989. "Lease Financing a VSAT Network." *Satellite Communications*.

McQuillan Consulting Presentation. January 1992. *Communications Networks Conference Proceedings* .

Moeller, Dick. Video Telecom CEO. COMNET '92.

Moeller, Dick. March 1990. "Has Videoconferencing Found Its Niche?" *Networking Management*.

Newsbytes. 23 April 1992. "Hughes Plans Direct Broadcast of up to 150 Channels."

Northern Telecom, Product Literature.

Polti, Carol. A., and John A. Stein. February 1991. "VSATs Give Corporate Networks a Lift." *Data Communications*. 89(5).

RKM Associates. October 1991. "International On-Board VSAT—Data and Voice Applications, NASA."

Roberts, Anne Marie. May 1990. "Private Networks Directory." *Satellite Communications*. 30(5).

Schultz, B. 6 April 1992. "Covia Test-Flies Hybrid Frame Relay Network." *Communications Week*. 1.

Schultz, B.. 30 March 1991. "Common SMDS Interface In Progress" *Communications Week* . 21.

Schwartz, Jeffrey. February 1992. "GTE Spacenet VSAT Gear Targets Retail Applications." *Communications Week.*

Sharma, Ranjana. February 1989. "VSAT Network Economics: A Comparative Analysis." *IEEE Communications Magazine*.

Simo, Dr. Ernest. November 1990. "VSAT's Slice of the Market." *Satellite Communications*. 42(4).

Taff, Anita. March 30, 1992. "AT&T, MCI Prepare to Launch SMDS." *Network World*, Vol. 9, No. 13.

Tagare, N. 20 May 1991. "A New Industry Is Born." *Telephony*. 30.

Tasrdif, Leila. 4 March 1991. *Computer Letter*. 7:1.

Tasrdif, Leila. 16 September 1991. "Intelsat Threatens Motorola's Global Phone System."

Tasrdif, Leila. 3 December 1990. "Iridium System Application to the FCC." Washington D.C.: Motorola Satellite Communications Inc.

Tasrdif, Leila. 18 October 1991. "New Global Mobile Satellite System Planned." *Exchange*. 3.

Tasrdif, Leila. 13 April 1992. "Orbcomm, Starsys Get Experimental Licenses to Test LEO Satellite System Proposals." *Telecommunications Reports*. 29.

Tasrdif, Leila. 28 March 1991. "Mobile Satellite Links Benefit Transportation Industry." *Computing Canada*. 17:24.

Tasrdif, Leila. 4 March 1991. "Into the Ether." *Computer Letter*. 7:1.

Taylor, Ron. August 1991. "Videoconferencing–Building Ubiquity, Cutting Costs, and Communicating Easily." *Telecommunications*.

Telecommunications. January 1990. "Hubless VSAT Networks." 54(3).

Telephone Engineering & Management Magazine. January 1992. *A Light at the End of the Loop* Supplement.

Thyfault, M. 27 April 1992. "BT, Nynex Boost Frame Relay." *Information Week*. 46.

Toda, I. April 1990. "Migration to Broadband ISDN." *IEEE Communications Magazine.*

U.S. Department of Commerce. January 1991. *U.S. Industrial Outlook—1991.*

U.S. Department of Commerce. June 1992. *Space Business Indicators.*

The Wall Street Journal. 10 April 1992. "FCC Proposal for HDTV May Restrict Broadcasters."

The Wall Street Journal. 12 February 1992. "COMSAT Sees Growth Despite Expanding Competition."

Wallace, B. 13 January 1992. "Private-Line Base Shapes Big 3's Frame Relay Plans." *Network World.* 1.

Wallace, R. 30 March 1992. "AT&T Plans Broadband SDN." *Network World.*

Walsh, John. Senior Vice President of Planning and Strategy, Compression Labs, Inc. 15 May 1992. Presentation at Telestrategies conference. Reston, VA.

Walsh, John. November 1989. "Videoconferencing Comes of Age." *Telecommunications.*

Walters, S. September 1991. "A New Direction For Broadband ISDN." *IEEE Communications Magazine.*

Wilson, T. 18 May 1992. "AT&T, GTE, and Pacific Bell Will Go The Distance In SMDS Trial." *Communications Week.* 5.

Wilson, T. 25 May 1992. "Local Carriers Layout Data Service Agenda." *Communications Week.* 1.

Wood, Peter. November 1991. "Mobile Satellite Services for Travellers." *IEEE Communications Magazine.*

Zerbiec, T. March 1992. "Considering The Past And Anticipating The Future Of Private Data Networks." *IEEE Communications Magazine.* 36.

SECTION 5 REFERENCES

Golshan, N. March 1992. *Direct Broadcast Satellite - Radio: Systems Tradeoff Study, Final Report.* JPL Internal Document D-9550, Jet Propulsion Laboratory, Pasadena, CA.

Hollansworth, J.E. October 1992. *Direct Broadcast Satellite - Radio Program.* NASA Technical Memorandum 105910.

Kratochvil, Dan. May 1991. Private conversation.

Leibowitz, Matthew L. Esq. and Thomas J. Buono. 1989. *Radio Acquisition Handbook.* BIA Publications, Inc.

Sood, D.R. 1991. *Direct Broadcast Satellite - Radio: Market, Legal, Regulatory, and Business Considerations - Summary.* Contel Federal Systems, Government Networks Group. NASA Contract No. NAS3-25083, NASA CR-187093.

U.S. Department of Commerce, National Telecommunications and Information Administration. October 1991. *The NTIA Infrastructure Report: Telecommunications in the Age of Information.*

Wilde, Candie. January 1992. "The 1992 Data Communications Market Forecast." *Data Communications.*

SECTION 4 REFERENCES

Appleby, C., and S. Stahl. 18 May 1992. "LAN Integration." *Information Week*. 68.

Barton, S.K., and J.R. Norbury. 1990. "Future Mobile Satellite Communication Concepts at 20/30 GH." Proceedings of the International Mobile Satellite Conference. Ottawa, Canada. 64–69.

Barsh, B.E. et al. August 1991. "VISTAnet: A BISDN Field Trial." *IEEE LTS Magazine*.

Beakley, G.W. et al. June 26, 1992. "An Evaluation of Digital High-Definition Television Transmitted Through NASA Communications Systems." NASA Contract No. NASW-4376.

Bell Atlantic Presentation. January 1992. *Communications Networks Conference Proceedings*.

Bellcore Fiber in the Loop Architecture Summary Study. June 1990. SR-TSY-001681.

Bennett, Tamara. July 1988. "Private Networks Directory." *Satellite Communications*. 30(5).

BIS Strategic Decisions. "Emerging Applications of High-Bandwidth Services."

Boeke, Cynthia. February 1992. "VSATs in the United States."

Booz·Allen & Hamilton. September 5, 1991. "Videoconferencing Internal Study Final Report."

Brown, Bob. April 1991. "VSAT Firms Shrink Gear to Cut Net Costs." *Network World*. 9(2).

Byrne, W. et al. January 1991. "Evolution of Metropolitan Area Networks to Broadband ISDN." IEEE Communications Magazine. 69.

Bull, Simon. March 1991. "Steady Worldwide Growth for VSATs." *Communications International*. 67(3).

Cacciamani, Dr. Eugene R., and Carol A. Polti. November 1991. "VSATs Take LANs Airborne." *Networking Management*. 54(4).

Caprioglio, Albert F. March 1992. Private conversation.

CCITT. May 1990. "BISDN Service Aspects, Study Group XVIII." Draft Recommendation I.211. Geneva.

Chakraborty, D. May 1988. "VSAT Communications Networks: An Overview. *IEEE Communications Magazine*. 10–24.

Communications Week Staff. 18 May 1991. "The Dawn of ATM Networking." *Communications Week..*

Coudreuse, J. P. August 1991. "Network Evolution Towards BISDN." *IEEE LTS Magazine.*

Egan, Bruce. 1991. *Information Superhighway.* Artech House Press.

Finn, C. 3 February 1992. "Buyers Guide–Frame Relay." *Network World .* 31–37.

Foley, Jim. October 1991. "Iridium: Key to Worldwide Cellular Communications." *Telecommunications.* 23–28.

The 14th International Communication Satellite Systems Conference, Colloquium. 22 March 1992.

Frame, M. April 1990. "Broadband Service Needs." *IEEE Communications Magazine.*

Fredericks, Robert M. Executive Director, Video and Data Services, Bellcore. 15 May 1992. Presentation at Telestrategies conference. Reston, VA.

Froyd, P. 1992. "Bell Atlantic's Switched Multi-Megabit Data Service (SMDS)." *Communication Networks Proceedings.*

Gareiss, R. 20 April 1992. "Regional Bells Will Stand Together On Frame Relay." *Communications Week.*

Gareiss, R. 27 January 1992. "Number of Carriers Offering Frame Relay Continues To Grow." *Communications Week.*

Gartner Group Consulting. September 1991. "Wireless Communications Market Overview and Analysis." JPL Contract No. 958857.

Handel & Huber. 1991. *Integrated Broadband Networks.* New York: Addison-Wesley Press.

Hassinger, W. August 1991. "FCC Policy on HDTV." *IEEE Communications Magazine.*

International Data Corp. April 1992. "1991 U.S. VSAT Market." *Network World.* 1(1).

Killette, K. 2 March 1992. "Bells Ready Frame Relay." *Communications Week.* 1.

Killette, K.. 3 February 1992. "GSA Signs Up For Bell Atlantic's 'Pre-SMDS'." *Communications Week.* 4.

Killette, K.. 20 January 1992. "New SMDS-Link Specs." *Communications Week.* 41.

SECTION 6 REFERENCES

Abernathy, Avery M. April/May 1992. "Difference Between Advertising and Programme Exposure For Car Radio Listening." *Journal of Advertising Research.* 31(2):33–42.

Ballman, Barbara. 15 July 1991. "Radio Operators Paying for Growth Binge in '80s." *Capital District Business Review.* 18:1.

Boyd, John, Northern Telecom. 15 May 1992. Presentation at Telestrategies conference. Washington, D.C.

Briskman, Robert. 22 June 1992. Telephone discussion.

Broadcasting. 2 July 1990. "NAB Radio Board Opposes Some DAB Services." 119:57.

Broadcasting. 29 October 1990. vol 119.

Broitman, Robin, Manager of Business Planning, GTE Telephone Operations. 15 May 1992. Presentation at Telestrategies conference. Washington, D.C.

Comsat Laboratories, Space Systems/Loral, Mar-Tech Strategies, Inc. May 1992. "Future Benefits And Applications of Intelligent On-Board Processing to VSAT Services." Final Review Briefing for NASA Contract No. NAS3-25092, Technical Support for Defining Advanced Satellite Systems and Concepts.

EDGE Publishing. 13 April 1992. "Satellite Broadcast: Thomson Selects Compression Labs To Supply MPEG Coding System for Hughes Direct TV System." *EDGE On and About AT&T.* 7:19.

FCC. CC Docket No. 87-313, "In the Matter of Policy and Rules Concerning Rates for Dominant Carrier." 97–130.

Heltai, Blaise. AT&T Bell Laboratories. 15 May 1992. Presentation at Telestrategies conference. Reston, VA.

Hock, Sandy. 15 April 1991. "Digital Radio Picks Up San Diego Funding, Feedback." *San Diego Business Journal.* 12:9.

Juliussen, Karen, and Egil Juliussen. 1990. *Computer Industry Almanac 1990.* New York: Simon and Schuster.

Kennedy, Connie, Strategic Project Manager, US West, Inc. 15 May 1992. Presentation at Telestrategies conference. Washington, D.C.

Kimball, Allen C. 22 July 1991. "Ratings: Key to Ad Revenues." *Austin Business Journal.* 11:9.

Leibowitz, Dennis, Eric Buck, and Joel Gross. Spring 1990. *The Cellular Communications Industry*. New York: Donaldson, Lufkin and Jenrette Securities Corporation. 8,9.

Miyazawa, Masayuki. 12 March 1992. "Digital Music Radio Broadcasting Starts Soon in Japan." *Newsbytes*.

———. 19 March 1992. "Lower-Cost HDTV from Hitachi." *Newsbytes*.

Norris, Eileen. 30 November 1987. "Media Outlook: Network Radio Upheaval Leaves A Powerful Few." *Advertising Age*. 58:S18.

Parker, Edwin B., and Joseph Rinde. September 1988. "Transaction Network Applications with User Premises Earth Stations." *IEEE Communications Magazine*.

Porter, Michael E. 1985. *Competitive Advantage*. New York: The Free Press. 11.

Proceedings of the International Conference on Satellite Communications and Broadcasting. December 1986. "Trends in Satellite Technology." London. 97–130.

Rigney, Melanie. 9 September 1991. "New Technology Brings Radio to Cutting Edge." *Advertising Age*. 62:54–58.

Sharma, Ranjana. February 1989. "VSAT Network Economics: A Comparative Analysis." *IEEE Communications Magazine*. 31.

Sherman, Barry L. 1987. *Telecommunications Management.*. New York: McGraw Hill. 83.

U.S. Government Printing Office. 1986. *Investing in Broadcast Stations*. Washington, D.C.

Weber, Jonathan. 22 April 1991. "High-Tech Radio Sparks and Industry Debate." *Los Angeles Times*. 110:1.

Willis, Edgar E., and Henry B. Aldridge. 1992. *TV, Cable and Radio: A Communications Approach*. Englewood Cliffs, NJ: Prentice Hall.

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13. ABSTRACT ***(Maximum 200 words)***

This report identifies trends in the volume and type of traffic offered to the U.S. domestic communications infrastructure, and extrapolates these trends through the year 2011. To describe how telecommunications service providers are adapting to the identified trends, this report assesses the status, plans, and capacity of the domestic communications infrastructure. Cable, satellite, and radio components of the infrastructure are examined separately.

The report also assesses the following major applications making use of the infrastructure.

- Broadband services, including Broadband Integrated Services Digital Network (BISDN), Switched Multimegabit Data Service (SMDS), and frame relay
- Mobile services, including voice, location, and paging
- Very Small Aperture Terminals (VSAT), including mesh VSAT
- Direct Broadcast Satellite (DBS) for audio and video.

The report associates satellite implementation of specific applications with market segments appropriate to their features and capabilities. The volume and dollar value of these market segments are estimated. For the satellite applications able to address the needs of significant market segments, the report also examines the potential of each satellite-based application to capture business from alternative technologies.

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